METALLURGIA

The British Journal of Metals

(Incorporating The Metallurgical Engineer.)

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Copper Mining and Smelting in Germany

INTERESTING PROCESSES AT MANSFELD

By O. BERTOYA

The agglomeration of mines and smelting works situated at the foot of the Harz presents many unique and peculiar features. In this article this little-known copper-mining area is described, and the method of mining, smelting and refining is discussed.

EXTENDING over a few square miles at the foot of the south slopes of that mysterious central German mountain known as the Harz, is located a most interesting, if relatively little-known copper-mining and smelting area. With a history reaching right back into the darkness of the middle ages, this agglomeration of mines and smelting works presents many unique and peculiar features, the unusual manner in which the ore occurs, and in which it is mined, smelted and refined forming a subject of considerable general and economic interest well worthy of study. For if these mines can no longer claim to supply the whole of the European copper requirements, as they did many centuries ago, they are the only important source of this metal available in the German Empire to-day.

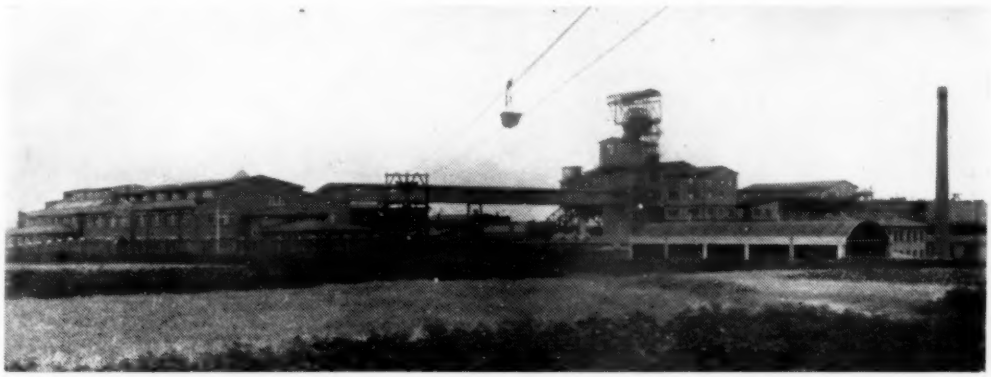


Fig. 1.
General view of the "Wolfschacht" at Eisleben.

During many hundreds of years intimately connected with the family history of the Counts of Mansfeld, this district is now in the hands of a limited liability company, at present operating under the name of Mansfeldische Kupferschieferbergbau A.G., with its seat in Eisleben, a small town near Halle, the centre of the German lignite industry. This company, having a capital of R.4. 6,000,000 owns the copper mines and smelting works. To the Parent company, the Mansfeld A.G., belong potash mines, the metal-working plants, chiefly brass and copper rolling mills, and the subsidiary companies. The concern employs in normal times approximately 27,000 people. The declared capital is R.M. 38,000,000, at par £1,900,000.

The Mansfeld mining area is a basin-like district some 15 miles wide and 20 miles long, sloping from west to east. The ore beds, of alluvial origin, are made up of inclined parallel layers of bituminous copper- and silver-bearing shale, averaging only 8 in. to 10 in. in thickness. These beds follow the general configuration of the basin and are also inclined from west to east so that mining operations, resolving themselves in the early days in simple surface extraction, have become more and more arduous with time, increasingly deep shafts having had to be sunk, the largest and most modern of these being over 2,500 ft. deep. The small thickness of the shale beds and the poorness of the ore mined (3–4% copper) leave a very small working margin indeed.

The profitability of the undertaking therefore, depends largely on the utilisation of all by-products and on the extraction of the more valuable and rarer metals which the ore contains to a larger degree than many other richer beds. The wide fluctuations in the composition of the ore mined further increase the costs of extraction and the difficulty of ensuring the necessary flexibility in following the world copper prices. Accordingly, the whole of the smelting and refining processes are designed to ensure the completest extraction possible of all profit bearing metals and the most rational recuperation of the valuable by-products. The margin of profit has been further increased by the addition of plant transforming the smelted metals into finished material and it has been possible to ensure a certain independency of world metal prices, thus enabling the concern to operate on a wider and securer basis.

The shale is mined with pneumatic tools, a portion of the rock being removed with the ore and subsequently smelted with it. The mass mined is locally called "minern." As already stated the shale itself is of 8 in to 10 in thick, bearing a mixture of minerals imbedded in the bituminous mass proper. The most common of these are: bornite ($3\ Cu_2\ S \cdot Fe_2\ S_3$), chalcocite ($Cu_2\ S$), copper pyrites ($Cu\ S \cdot Fe\ S$) pyrites ($Fe\ S_2$), zinc blende ($Zn\ S$), metallic silver, galena ($Pb\ S$); further: lead, nickel and cobalt minerals. The rarer elements are also represented; gallium, platinum, germanium, palladium, gold, and the newest of these, rhenium, having been traced in the by-products.

Fig. 2. Mining the copper-bearing shale.

As already pointed out the copper content of the shale is low, average only about 3%. Fortunately, the relatively large quantity of silver which accompanies it—0.01 to 0.02%—materially improves the profitability of the extraction processes. The composition of the ore mined varies considerably. The following analysis (Dr. Wagenmann), however, may be considered as typical:

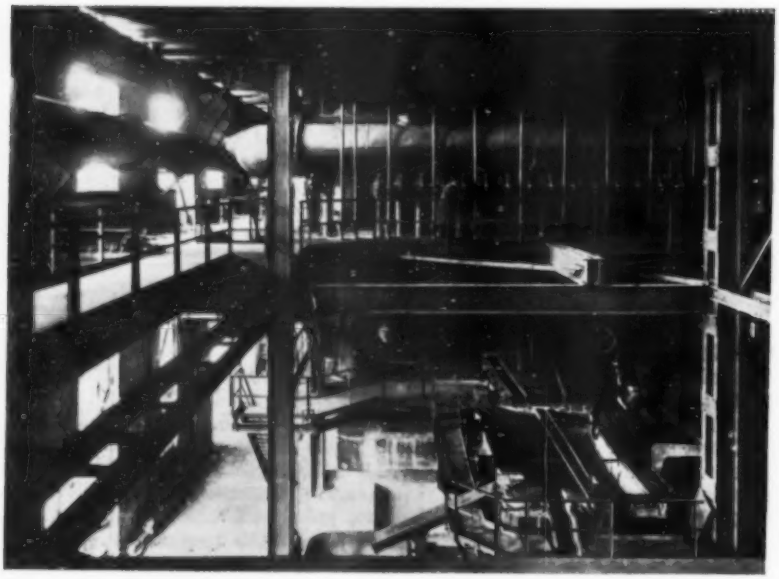
	%		%		%
SiO_2	33	S	2·6	Cl	·15
Al_2O_3	14	Fe	2·5	V	·05
Ca O	14	Zn	0·9	Ag	0·016
CO_2	13	SO_3 ..	0·8	Ni	0·01
C	5·5	Pb	0·5	Co	0·004
Mg O	4·8	Mn	0·3	Cr	0·01
K Na	4·4	Se	0·002	P_2O_5	0·2
Cu	2·9				

The copper occurs exclusively in the form of sulphides.

The ore is mined, as already said, with pneumatic tools and sent to the surface where it is screened and picked by hand. At present there are three shafts in operation; these supply the ore to the one smelter in Eisleben (Krug plant) and the second in Helbra (Koch smelter). Here the screened ore is fed direct to the water-jacketed blast-furnaces, the fine material having been previously agglomerated under the addition of coke. The charge consists of alternate layers of ore, limestone, the Bessemer slag produced at another stage of the extracting process, and of coke.

At Eisleben there are at present three water-jacketed furnaces in operation having a total maximum daily capacity of nearly two thousand tons of ore, two of them being in operation and one as reserve. The furnaces at Helbra are not jacketed but are cooled with a water spray. There are nine of them at this plant, of somewhat smaller capacity—160 tons of ore per 24 hours. The smelting process, which takes place in the furnaces, delivers a raw matte containing most of the copper and silver, leaving a slag poor in copper. The other metals pass over almost completely as sulphides in the raw matte, which contains 40 to 50% of copper.

Fig. 3. One of the smelting furnaces at Eisleben.



In earlier days the ore was roasted previous to smelting to drive off the bituminous matter, but this operation is no longer carried out, it being unnecessary with water-jacketed furnaces. The matte is separated from the slag in external settlers and poured out on a floor lined with cast-iron plates. It is subsequently broken up by hand into rough pieces, smelted down in reverberating furnaces, and fed into copper Bessemers.

Some two-thirds of the production are blown to the so-called "Spurstein" or white metal matte, containing some 70% copper. The remaining one-third is blown to "black copper" or blister for subsequent desilverisation. Sand is used as slagging medium. During blowing, owing to the greater affinity of sulphur for copper and silver than for the other metals the S of the iron sulphides burns first. The resulting iron oxide combines at once with the silica of the sand and slags off. At this stage the charge consists largely of a rich sulphuretted copper matte (73–74% Cu, 21% S –"Spur" matte) and slag, which, being lighter, floats on top of the molten mass. The heat produced in burning the sulphur suffices to keep the mass in a molten condition. At this stage the blowing is interrupted when making Spur mattes, the correct point being determined by the character of the flame. The slag is racked off after tilting the converter.

When making blister copper (Schwarzkupfer) blowing is continued after removal of the slag, the purpose being to burn off the remaining sulphur, leaving a mixture of raw copper oxide. When the whole of the sulphur is burnt blowing is discontinued, which point is reached when the converter flame changes from pale blue to reddish brown. The blister which collects at the bottom of the converter contains almost the totality of the silver present in the ore and most of the other metals. It is cast in bars, refined in flame furnaces to bring the copper contents up to 97·5/98·5%, and finally refined by electrolysis.

Since 1845 the "Spur" mattes obtained from Bessemering are desilverised by the so-called "Ziervogel" process, which replaced the costly lead process used previously following roasting. For this purpose the rich matte is ground in ball mills to a coarse powder and roasted in stage furnaces, the object being in the first place to burn off some 15% of the sulphur content, and to oxidise some of the copper, finally obtaining a mixture of copper oxide and copper sulphate which contains the whole of the Ag_2S present in the matte. The result is a powder-like substance which is allowed to cool, is then sifted and fed to a stage roasting furnace proper fitted with rotating arms. In the cooler top sections (750° C.) of these furnaces the remaining 5% of sulphur is oxidised to Cu SO_4 the Cu_2O present being oxidised to Cu O.

In the lower sections of the furnaces at the somewhat higher temperature of 850° C. the copper sulphate dissociates into oxygen and SO_2, the silver being oxidised to Ag_2 SO_4, which is soluble in water. On leaving the furnace the charge consists largely of a mixture of copper oxide and silver sulphate accompanied by metallic impurities.

Having remained in powder form, the charge is leached with weakly acidulated warm water, the liquor being passed subsequently through a cascade of tubs filled with granulated copper and copper bars, where it gives up its silver in the form of grey spongy deposit. The liquor remaining is pumped up to the first stage, warmed and used again for leaching a fresh charge. The silver is washed out of the tubs, filtered, dried, and refined (precipitated silver 999·3). The deposits accumulating from the leaching process, etc., are dried and refined.

Refining.

The copper blister is refined electrolytically, whereas the desilverised copper deposit is heated in reverberating furnaces where, in the presence of coke, it is reduced and finally poled. The charge contains 75 to 80% of copper. After refining it yields almost pure copper which is poured in bars of approximately 18 lb. weight, which find their way to the market under the mark M R A (Mansfeld Raffinade A). This product contains 99·7 to 99·8% of copper, the balance being made up of silver, lead, nickel and arsenic.

The slag obtained from the refining operation formed by combination with silica from the furnace lining (the hearth is lined with sand) is fairly rich in copper and naturally contains many other metallic impurities, chiefly nickel. It is reduced to copper which, owing to its nickel content, finds a demand for heat-resisting applications, particularly loco-boxes.

The copper blister, which is refined electrolytically in order to obtain a product of greater purity, and thus to meet the requirements of the electrical industry, is first of all refined in reverberating furnaces to increase the copper content, cast into anodes and sent to the electrolytic refinery at Ilsenburg (Harz).

The electrolyte consists of a solution of copper sulphate and sulphuric acid. The liquor must be kept clean and at the required degree of concentration. This is done by the periodical removing of a portion of the liquor, which is then replaced by fresh supplies. Active circulation must be maintained in the vats, which are interconnected for this purpose. The anodes are hung between two starting cathodes, on which the chemical pure copper precipitates. When they have attained sufficient bulk they are lifted out, washed and smelted down into bars, sold under the mark M.E.K. (Mansfelder Elektrolyt Kupfer).

The impurities contained in the anode separate out in the form of a slime mass which collects at the bottom of the bath. This slime contains all the silver and other rarer metals (gold, platinum, palladium). It is very valuable, and is therefore sifted to separate it from coarse copper rests, filtered and dried. It is subsequently roasted to oxidise the copper, which can then be extracted almost completely by leaching. The residue is dried and cast into raw silver anodes to be refined electrolytically. The anode slime which collects from this second electrolysis contains a fairly high percentage of gold, platinum, and palladium, which are also subsequently extracted according to a special process.

The chemically pure silver separates out in the form of bright needles, which fall to the bottom of the bath. To prevent the slime which is formed in turn from contaminating the silver the anode is enclosed in strong calico sacks in which the slimes collect. The sacks are withdrawn in due course, the contents shaken out, washed, dried, and treated as already explained.

By-products.

(*a*) *From the Smelting Process.*—The blast-furnace gases, after a first rough dry separation, contain a considerable

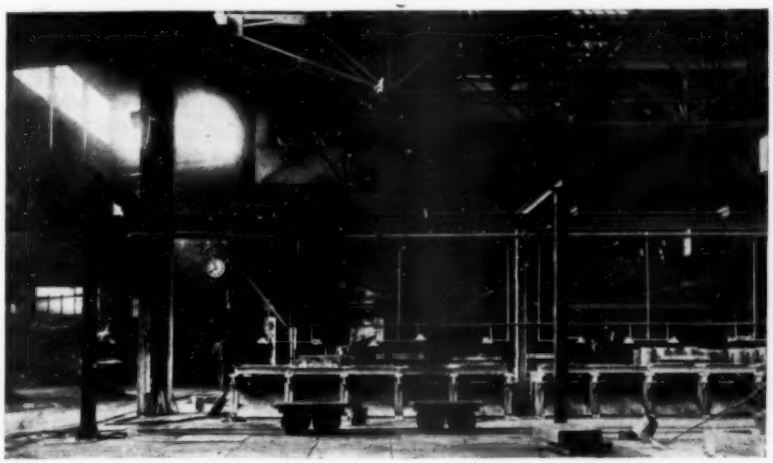
Fig. 4. Converter shed at Hettstedt.

percentage of valuable dust rich in lead and zinc, also silver. To recuperate these metals the gases are washed in a tower-like structure, passed through scrubbers and finally washed in cyclones or similar apparatus. The mud which collects in the various parts of the washers is run into collecting vats, where it is allowed to deposit and after decanting-off the water, dried into cakes. About 160,000 cub. metres of gas are dealt with per hour in this manner. The dust recuperated amounts to about 25,000 tons per year, or approximately 3% of the ore mined. It contains about 25% of zinc, approximately 20% of lead, sulphur and silica, and a small quantity of silver and copper. To extract these metals the mud is dried in rotary ovens and smelted in lead blast-furnaces. The metallic lead thus obtained is refined, desilverised and cast into bars. The slag produced in the lead blast-furnace, contains approximately 10% to 20% of Zn O. It is accordingly ground, mixed with limestone and coke and charged into rotary furnaces. The zinc which is reduced out in this operation evaporates and oxidises. On cooling it condenses as Zn O, in which form it is separated from the furnace gases by filtering.

The washed blast-furnace gas is burnt under boilers for generating power. It is of relatively low heating value, containing only about a sixth of its volume of CO, the balance being made up of nitrogen and CO_2 plus a little methane and hydrogen.

Valuable products are not only recuperated from the gases, the slag coming from the copper blast-furnaces has

Fig. 5. View in one of the casting rooms at the Hettstedt Works.



also found important outlets. It is poured into moulds of suitable shape, in which, allowed to cool slowly, it solidifies into hard blocks of greyish colour and first-rate noise-absorbing properties, which render them eminently suitable as paving stones. Large quantities are sold for this purpose and are being used on an extensive scale for street paving in Germany, Holland, Denmark, Sweden, etc. Defective blocks and rejects are broken in jaw crushers to road metal.

Fig. 6. Part view of the electrolytic refinery in Ilsenburg.

The fine material and dust falling out from the crushing operations is mixed with cement and pressed into blocks.

(*b*) *From converting.*—The converter gases are cleaned electrically in a Cotteril dust-precipitating plant, which is very effective indeed. The particles separated out consist, chiefly of zinc and lead sulphate, also other metallic and mineral impurities. They represent, therefore, a valuable by-product which finds a market for further treatment, principally for the extraction of pure zinc sulphate.

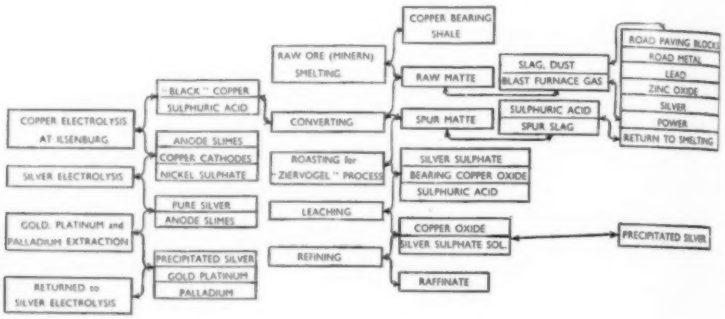
The cleaned gases still contain a considerable percentage of SO_2, which makes it worth while to treat them further for the manufacture of sulphuric acid, which is done in towers, the acid being subsequently concentrated to a saleable density in the usual way. In any case it would not be permissible to allow the Bessemer gases to escape freely in the air, as their SO_2 content would rapidly result in the destruction of the surrounding vegetation, which, in this case, is particularly undesirable, the plant being located in a thriving agricultural area. The SO_2 gases produced in roasting the charge in the desilverising Ziervogel process are oxidised to sulphuric acid in the same manner.

(*c*) *Various other by-products.*—The electrolyte, which is tapped continually from the refining baths, yields on further electrolysis a rather impure copper which, however, finds a market. The poor liquor left over from this operation yields in turn, on evaporation and crystallisation, copper and nickel sulphate. The anode slimes on the other hand are handled in the manner already described, and yield silver, gold, platinum, and palladium.

As will be seen this very interesting smelting plant has succeeded in making the most of none too favourable conditions, and has been successful in evolving processes and machinery which permit the almost complete utilisation of the treasures which mother earth delivers so sparingly and in such a diluted form in this mining area. And in spite of all the difficulties, its directors and employees have been able to build around this unique but poor source of riches a concern playing a most important part in German economic life, as the following figures will show :

1930—Ore mined	809,000	tons
Copper produced	21,000	,,
Fine silver	109,000	kg.
Lead	2,200	tons
Zinc oxide	7,000	,,
Zinc sulphate	2,000	,,
Sulphuric acid	39,000	,,
Paving stones	17,800	(thousands)
Coal extracted	531,000	tons
Coke	286,000	,,
Lignite, etc.	2,500,000	,,

Ample and regular supplies of coal are ensured by the concern's coal mines in Langendreer and Heesen in Westfalia. Both these mines produce some 1,300,000 tons annually. Apart from this, control over the Hallesche Pfannerschaft in Halle ensures an adequate supply of lignite for power purposes and gives a broader basis to the mining interests of the concern, which have widened still further by the acquisition of potash and salt mines.



Flow sheet at Mansfeld, compiled by Dr. Wagenmann.

Again, a good percentage of the raw metals produced at the Krug and Koch smelters are transformed within the concern itself, various metal-working plants being owned by the company. The modern copper and brass plant at Hettstedt, for instance, makes sheet, tube, rod, wire, cable and netting either in copper or bronze, brass, gun-metal and German silver. A smaller plant in Düsseldorf specialises in silverware.

World's Largest Ball-bearing Plant to be Built at Saratox

Preparations are now being made for the construction of a large ball-bearing plant, said to be the largest in the world, in Saratov. The technical details of the plan will be completed by October 1. The output capacity of the new plant will it is stated be double that of the ball-bearing plant in Moscow. It is planned for an annual production of 50 million ball-bearings of 250 types.

The Saratov plant will be built on the Volga, outside the city. Housing construction and making of roads, temporary garages and workshops for the concrete plant are already in progress. Occupying a total area of 175 acres, the principal block of the plant will take up 200,000 sq. metres. The plant will be equipped with 8,000 lathes and machines, and when working at full capacity will employ 27,000 workers, of whom 3,000 will be technicians and engineers.

A special department will produce special ball-bearings to meet the needs of small consumers.

With the building of this plant at Saratov, the Soviet Union will be practically independent of imports in this field. The tractor and harvester industries will be supplied by the new giant plant, while the Moscow Ball-Bearing Plant will continue to meet the needs of all other branches of industry.

Obituary

Mr. James Peech, one of the best known figures in the steel industry in this country, died on October 7. Mr. Peech, who was 62 years of age, had been connected with the manufacture of steel since he was 19. He was the son of the late Mr. William Peech, one of the original founders of Steel, Peech and Tozer, Ltd., and was a director of that company ; later he became a director of The United Steel Companies Ltd.

Mr. Peech was particularly well known in the railway world, and had travelled extensively on behalf of The United Steel Companies Ltd., on railway business, particularly in Canada, China, South Africa and Egypt. His loss will be mourned by many business and personal friends.

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Metallurgy and Motor-car Production

THE automobile industry has been hard at work during recent weeks preparing for the twenty-ninth Motor Show at Olympia, officially opened by H.R.H. the Prince of Wales, on Thursday, October 17. Some 500 cars are on view, and, as in former years, the exhibition is international in character; British cars being shown under conditions which enable comparisons to be made with those of their rivals in home and world markets. There are 59 different makes of cars shown, of which 30 are British, 15 are American, and 14 by Continental manufacturers. Each successive exhibition reveals the intense activity of this industry, and there is no indication of any curtailment in the enthusiasm which prevails. It is probably due to enthusiasm within the industry that the Motor Show continues year by year to exert a fascinating influence on motorists and prospective motorists. Although there is nothing of a revolutionary kind at Olympia, intense rivalry in the home market, as well as abroad, keeps the manufacturer alive to the need for progress, and further mechanical improvements have been made to simplify driving and provide greater comfort, while at the same time improving the efficiency and reliability of the car.

Simultaneously with the Motor Show at Olympia the Ford Motor Company is exhibiting models at the Royal Albert Hall, at which considerable attention is given to the remarkable engine exchange plan. This plan, which not only concerns the replacement of engine units, but also subsidiary parts, is designed to restore a car to its former performance.

It is noteworthy that the trend in manufacture, as exhibited at these shows, is the increased average horse-power of the motor-cars. Last year the average car was of 15 h.p.; this year the average is 19 h.p. Six-cylinder engines are more numerous, and there are indications that 8- and even 12-cylinder engines have a certain amount of popularity. Another important feature is the efforts made to satisfy the growing interest in the mechanical side of motoring. It is interesting to note the increasing number of firms that display stripped chassis and dismantled engines for the enthusiast's inspection. But many manufacturers have the courage to carry this a step farther, and define the materials of which the various parts are made. Thus, the Humber exhibits display new engine features and refinements including aluminium-alloy cylinder heads giving higher compression ratio; lead-bronze main bearings which are claimed to set an altogether higher standard of durability; and it is further claimed that no matter how much the brakes are ill-treated or over-heated, due to the fitment of a one-piece drum of "milenite," no distortion problems can possibly arise. It is noteworthy that in the new Ford V 8 the crankshaft is not forged, but is made of a new cast alloy steel. This material is claimed to be twice as resistant to bending strains as forged steel, and is so tough and hard of surface that tests reveal no measurable wear after 10,000 miles of engine operation. In the engine of this car the pistons are stated to be of light-weight copper silicon steel, matched accurately in weight to within two grams. The synchromesh gearbox of the Alvis car is another example of efforts made to give information of materials used. Here we are informed that the first and reverse gears are of nickel-chromium case-hardened steel; double helical gears are air-hardened nickel-chromium steel; all forward gear engagement sleeves are of bronze; mainshaft and lay-shaft are in manganese case-hardened steel; while the gear-case is composed of aluminium alloy. Although only a few instances have been mentioned, actually there are few firms exhibiting which do not give some information regarding the materials employed in the cars on view.

The trend in this direction seems to indicate that, in addition to becoming mechanical-minded, the motorist may also become metal-minded, and be able to discuss the relative advantages of this or that metal or alloy for the various components of a car. Even to-day a knowledge of the characteristics of materials used for the vital components is being recognised as of considerable value, and a wider knowledge of the subject would tend to further improve the position of British motor-car manufacturers. The quality of the materials employed, in addition to ingenuity, resourcefulness and enterprise has enabled Britain to lead the world in automobile construction, and it is the application of metallurgical developments which explains, in some measure, why foreign markets are British-motor minded. For this reason manufacturers have nothing to lose and much to gain by fostering the desire for information on the structural materials employed.

There is much truth in the statement that no industry has given greater attention to the application of metallurgical developments than the automobile industry, and the variety of both ferrous and non-ferrous metals and alloys used in a modern motor-car is very considerable. On the ferrous side carbon steels continue to be used for constructional purposes and many engine components; there has been little change in this type of steel, except in quality and reliability. The range of carbon content is wide, and provides for many different purposes, from the dead-soft material suitable for deep pressing to the high-carbon steels such as are used for high-tensile wire for valve springs. The use of low alloy and high-tensile alloy steels, however, is increasing, the former including the nickel steels, molybdenum-manganese steels and chromium-molybdenum steels; and the latter the nickel-chromium and nickel-chromium-molybdenum types of alloy steels. Case-hardened alloy steels, because of their tougher core and harder-wearing surface, are used for many engine details in preference to case-hardened carbon steels.

Probably the most important change in automobile engineering in recent years is the use of light alloys. In addition to reliability and endurance of the components, the desire to reduce weight per horse-power has resulted in striking advances and the adoption of high-strength light alloys for such parts as crankcases, cylinder heads and pistons. Besides major components, light alloys are being used for panelling, not only in luxury cars, but in quite cheap mass-produced cars. The use of these alloys is being developed rapidly, but it should be appreciated that, whatever types of metals and alloys are used, there is constant need for metallurgical and physical control to ensure the quality of the final production, and the majority of British manufacturers regard the metallurgical and inspection departments as of vital importance.

BRITISH FOUNDRY SCHOOL

The governing body of the British Foundry School announces that the school will open for its first session on October 15. The governing body is comprised of representatives of institutions and firms supporting the scheme, and ample provision exists for the representation of subscribing firms, from whom additions to the governing body will be made. Eleven students have registered for the first session, being nominated by firms which, in the majority of cases, are members of the British Cast-Iron Research Association, and/or of the British Non-Ferrous Metals Research Association. In most cases nominating firms provide fees and maintenance for their students. It should be noted, however, that students at present unattached to a particular foundry may apply for admission, and in some areas it will be possible to arrange for such students to be assisted by their local Education Authority.

It is estimated that the annual cost of this school, less receipts from students' fees, will be £2,000. Subject to the industry raising the sum of £500 per annum, the Board of Education has undertaken to furnish the remainder as grant. A group of co-operating institutions has undertaken to provide towards the first year's working the sum of £195, and contributions have also been received from a number of industrial firms and persons, totalling £208. The sum of £97 is therefore required to make up the £500 from the industry for the first year's working, and contributions are invited from those firms and persons who are interested and who recognise the importance of the scheme.

Prospective students are reminded that there is still time for prospective candidates to enter for the first year's course. Candidates must have had practical experience in the industry, and must have reached a suitable stage of preliminary education so as to ensure their being able to profit by the instruction. Further information may be obtained from the Secretary of the School, or Principal, Birmingham Central Technical College, or from the Hon. Secretary, 21, St. Paul's Square, Birmingham 3.

Titanium in Canada.

THE Dominion Department of Mines, at Ottawa, advises that there is evidence in Canada of an increasing interest in the development of Canadian titanium-bearing deposits. The communication states that of the three titanium-bearing minerals which may be classed as ores—namely, rutile, ilmenite, and titaniferous magnetite,—the known deposits in Canada that are both large enough and rich enough to be of commercial interest, all occur in the provinces of Quebec and Ontario. The most desirable ones, rutile and ilmenite, are found in quantity only in Quebec, the Ontario deposits of any considerable size all consisting of titaniferous magnetite.

In Quebec, ilmenite, carrying from 18 to 25% titanium, occurs in large bodies at Ivry, Terrebonne County, and St. Urbain, Charlevoix County. Occasionally small shipments have been made from both these places during the last 20 years, chiefly from St. Urbain. Practically all of the ore shipped has been exported to the United States. Rutile, associated with the ilmenite in one of the St. Urbain deposits, is the only potentially commercial source of the mineral known in Canada.

Titaniferous magnetites, carrying 5% and upwards of titanium, are found at numerous localities in both Ontario and Quebec. Among the largest of these deposits may be mentioned those in the vicinity of Seine Bay, Rainy Lake, in the Rainy Lake district of Ontario, which are also vanadiferous; those on the Saguenay River, in Chicoutimi County, Quebec; and those at Bay of Seven Islands, Saguenay County, Quebec.

Titanium is used principally in the production of white non-poisonous pigments of great covering power, and in ferro-titanium alloys for use in steel-making. The use of the white pigments has expanded rapidly in recent years. Rutile is used in the ceramic industry as a colouring material, especially in the manufacture of artificial teeth. Various compounds of titanium are used in the textile and leather industries as dyes and mordants.

Forthcoming Meetings

INSTITUTION OF MECHANICAL ENGINEERS.

Oct. 25. General Meeting. Presidential Address by Col. A. E. Davidson, D.S.O., A.D.C.

Nov. 1. Extra General Meeting. "Strength of Metals under Combined Alternating Stresses," by H. J. Gough, M.B.E., D.Sc., Ph.D., and H. V. Pollard, A.M.I.Mech.E.

IRON AND STEEL INSTITUTE.

Oct. 18. Joint Meeting of the Iron and Steel Institute and The West of Scotland Iron and Steel Institute at the Royal Technical College, Glasgow.

Nov. 12. Joint Meeting of the Iron and Steel Institute and the Lincolnshire Iron and Steel Institute, at Scunthorpe.

INSTITUTE OF METALS.

BIRMINGHAM SECTION.

Oct. 24. "The Production and Control of Bronze Castings," by Francis W. Rowe, B.Sc.

Nov. 7. "The Hot Rolling of Sheets." Open discussion.

LONDON SECTION.

Nov. 7. "The Ultimate Strength of Metals," by E. N. da C. Andrade, D.Sc., Ph.D., at the Royal School of Mines.

MANCHESTER METALLURGICAL SOCIETY.

Nov. 6. Joint Meeting with Institute of Metals.

NORTH-EAST COAST SECTION.

Nov. 12. "The Manufacture of Zinc," by Stanley Robson, M.Sc.

SCOTTISH SECTION.

Nov. 11. Chairman's Address, by J. W. Donaldson, D.Sc.

SHEFFIELD SECTION.

Nov. 8. "Rolled Gold and its Industrial Applications," by E. A. Smith, A.R.S.M.

SWANSEA SECTION.

Nov. 12. Chairman's Address. Roosevelt Griffiths, M.Sc.

INSTITUTE OF BRITISH FOUNDRYMEN.

BIRMINGHAM BRANCH.

Nov. 1. "Refractories for Foundry Use," by W. J. Rees, M.Sc.

EAST MIDLANDS BRANCH.

Oct. 26. "Microscopy of Cast Metals," by L. E. Benson, M.Sc.

Nov. 1. "Some Details of Modern Foundry Control," by G. W. Brown, M.I.Mech.E. (Lincolnshire Section).

LANCASHIRE BRANCH.

Nov. 2. "Die Castings," by A. H. Mundey.

Nov. 12. "Castings Viewed from the Machine Shop *re* Machinability," by J. Jackson (Burnley Section).

LONDON BRANCH.

Nov. 6. "Welfare Work in Relation to Foundries," by R. R. Hyde.

MIDDLESBROUGH BRANCH.

Oct. 18. "A Talk on the Production of Steel Castings," by J. G. Wrightson.

NEWCASTLE-UPON-TYNE BRANCH.

Oct. 19. Visit of Council of the Institute.

SCOTTISH BRANCH.

Nov. 9. "The Balanced Blast Cupola," by W. Y. Buchanan.

SHEFFIELD BRANCH.

Oct. 18. "System in the Selling of Castings," by E. N. Simons.

Nov. 15. "Refractories in the Foundry," by W. J. Rees, M.Sc.

A New Piston Alloy.

Our attention has been directed to the remarkable physical properties claimed for a new alloy, known as "Pistonel," particulars of which were published in our last issue. It will be appreciated that new alloys, for which special properties are claimed, appear continually. The number of aluminium alloys, for instance, which are announced and patented every year must be very considerable. While every care is exercised in referring to new alloys in this publication, it will be appreciated that we accept no responsibility for the accuracy of claims made by those responsible for new alloys.—EDITOR.

High-Manganese Steel

By L. SANDERSON

Manganese steel is not in itself a hard material, even after forging and heat-treatment, but deformation such as wear or cutting alters its molecular surface structure in such a way as to heighten its resistance to these actions. In this article the characteristics of this steel are discussed, and practical suggestions given for its successful manipulation.

HIGH-manganese steel is that which contains from 12.14% of manganese in its composition, and is quite often termed "Hadfield" manganese steel. While generally known as a highly wear-resistant material, of great value in crushing and grinding machinery, where it is employed for wearing parts, such as jaws, side-plates, rolls, pug-mill-knives, liners, and the like; and in railway and tramway special track work, for points, junctions, crossings, and switches, some of its special characteristics and less well-understood applications are not so familiar.

By courtesy of Hadfield's Ltd.

A wide range of castings in high-manganese steel.

It has often been asked why manganese steel cannot be employed, for example, for shafts and journals subject to much friction. The answer is that this steel has a low yield-point, and if the shaft were subjected to excessive torque it might not withstand the strain. To fix a cylindrical shell of manganese steel on to an ordinary steel shaft, and so run out in a bearing of manganese steel, might give a very suitable wear-resisting arrangement, but it is unlikely that the extra durability thus gained would pay for the excessive cost of manufacturing the device. Manganese steel can be drop-forged, but extreme care is necessary if the process is to be carried out correctly, as the limits of temperature within which it can be worked are very small.

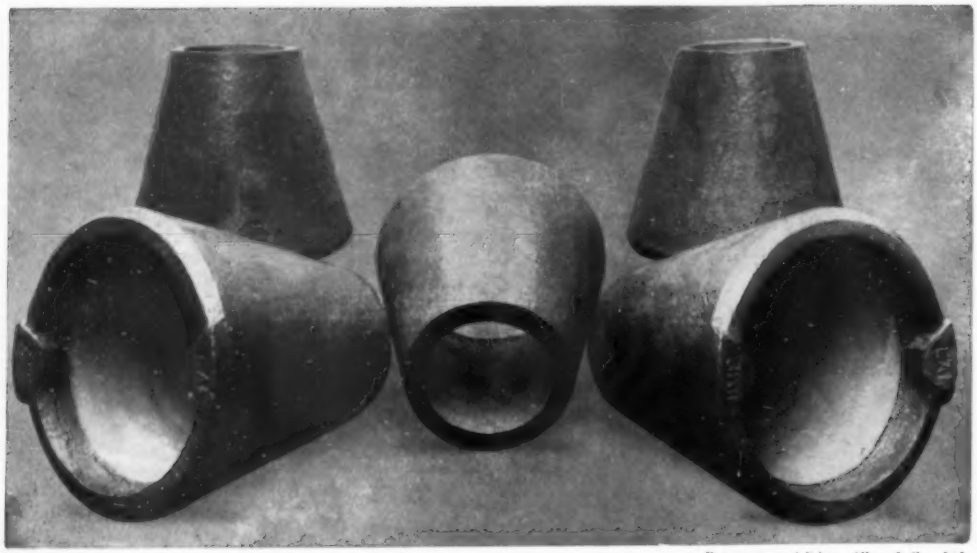
Engineers should note that the electrical specific resistance of manganese steel has been carefully tested by the Faraday House Testing Laboratories, of London. The resistance was measured between two points 28 ft. apart by the fall-of-potential method. The potential leads were connected to the steel by means of a bare copper wire fastened tightly round the metal, care being taken to remove the scale, so as to make a good contact. The result was as follows: resistance, 0·000967 ohm; temperature of the room, 61° F. The test, it should be mentioned, was carried out on a rail measuring 28 ft.

It is not widely known that manganese steel is not in itself a hard material, the Brinell being as low as 200, even after forging and heat-treatment; but deformation such as wear or cutting alters its molecular surface structure in such a way as to heighten its resistance to these actions. The effect of wear on the surface has, in fact, been measured. On manganese steel castings the increase of hardness due to wear averages about 107%. In the case of rolled manganese steel rails the increase is about 94%, but the rolled rail is itself very much harder to begin with than the casting. The fact that manganese steel is not, properly speaking, a hard metal explains why it cannot be used for cutting tools.

The carbon content of the material is usually 1·2%. In the freshly cast form it is brittle, too brittle for practical use until it has been reheated and quenched, after which it exhibits the characteristic property of ductility that renders it extremely valuable for many engineering purposes. This toughness is due to its very closely-knit and cohesive grain structure, the result of proper reheating and quenching. Its ductility, and its high degree of elongation, enable it to withstand shocks that would lead to the complete failure of an ordinary steel. Again, it is austenitic in structure, and therefore non-magnetic, which enables it to be distinguished immediately from ordinary iron or steel. The cause of this non-magnetic quality can be loosely explained as due to the high percentage of manganese in its composition preventing the molecular structure from aligning itself into paths of flow for magnetic lines of force.

When correctly heat-treated, manganese steel can be bent double while cold without fracture. This heat-treatment, as applied to cast manganese steel, consists of heating the steel to approximately 980° C., and then cooling rapidly in water. If the cooling is too slow, the precipitated carbides will lessen the toughness of the steel. It is preferable to remove the pieces from the quenching bath while still warm—*i.e.*, at about 205° C. This relieves the cooling strains, and no further tempering is necessary. It is possible, however, if desired, to give a separate temper at not above 370° C.

The brittleness presented by the steel in the freshly cast form, but removed by reheating and quenching, can, of course, be restored by heating it to over 390° C. Below this temperature, however, the material can be safely heated without losing any of its remarkable properties. For forging, one should heat thoroughly to the centre, then raise the heat gradually, frequently turning the piece in the fire, to a uniform bright-red colour. It should not be forged at a dull red. After forging, the part or piece should be reheated to the same uniform bright red (950-1,000° C.), plunged into cold water, and kept moving. This toughens the steel. It is worse than useless to plunge it at any other than a bright red. Those not familiar with the characteristics of the steel under the various temperatures often make mistakes in forging. The heavier pieces need reheat-



By courtesy of Edgar Allen & Co., Ltd.

Mantle castings in manganese steel.

treatment after forging, in order to restore them to uniform internal structure throughout. In this reheat-treating it should be borne in mind that a uniform temperature must be maintained throughout the whole piece dealt with, whether casting or other form.

Manganese steel castings contract on cooling like all other steel castings, but the rate of contraction varies from that of ordinary steel, being ⅛ in. to the foot. For this reason, and because proper heating through is necessary in the reheating process, patterns for manganese steel castings need special preparation, and the patterns employed for ordinary steel castings will not serve.

It has been mentioned in the course of these notes that manganese steel cannot be used as a cutting steel. It is not uninteresting, however, to bear in mind the statement made by Charles Vickers in his book, *Metals and Their Alloys*, in which it is said that "an excellent quality of razors and axes has been made from Hadfield's steel, containing 13.75% manganese and 0·85% carbon. The steel referred to may have been specially treated, or may have been employed in its hard and brittle condition; but the fact that the steel is never used to-day for these purposes is adequate evidence that whatever success was achieved in this direction was of short duration.

Manganese steel is frequently used for the facings of lifting magnets, and, on account of its non-magnetic qualities, for parts of electric-smelting furnaces where a light weight, high strength non-magnetic material, free of eddy currents, which can be fabricated to the required specifications, is desirable.

The fact that a number of the valuable characteristics of manganese steel are derived from heat-treatment has made the problem of welding it difficult. The high temperatures employed in welding have the effect of slightly altering the chemical and physical character of the metal. It is true that a second heat-treatment will restore the original properties in the main casting, but this is usually not practicable, and it is often very difficult to put right structural alterations in the narrow zone at the point of junction of the weld metal and the base material.

These difficulties have, however, recently disappeared, so far as electric welding is concerned, with the introduction of "Hadmang" welding electrodes, which are made of manganese steel of a patented composition, containing a proportion of nickel. The effect of these modifications in composition is to prevent the separation of carbide when the metal is slowly cooled from welding heat, or maintained in the "embrittling" range of temperature, so that the deposited metal, although it has cooled slowly, is tough. Furthermore, the composition of the parent metal near the weld is altered during welding by diffusion from the deposited metal, so that it also remains tough after welding.

Welds produced in this way have all the salient features of manganese steel without the liability of cracking and without the necessity for subsequent heat treatment which characterised the older type of welding rod.

Owing to the comparatively large area of metal which is inevitably heated when the oxy-acetylene process is used there is a great danger of a loss of toughness in the parent metal, and cracking due to thermal stress, so that this process should, if possible, be avoided, particularly when dealing with heavy articles.

To prepare a casting for oxy-acetylene welding when the use of this method is unavoidable, the edges should be bevelled to a 90° total vee, which is preferably done by grinding, though the oxy-acetylene blowpipe can be used, in which latter case the edges should be ground or pickled to remove the adhering scale. The actual welding operation should be preceded by a preheating process. Large castings can be heated up slowly in a charcoal-fired preheating furnace made of bricks. For the small castings, either a petrol preheating burner or even the welding blowpipe can be employed. Manganese steel is quite brittle when in the red-hot condition, and it is therefore essential that the castings should be carefully supported during preheating and welding. They should be welded in the preheating furnace, and draughts or sudden chills while hot should be rigorously prevented. Special manganese steel welding rods must be used. If oxy-acetylene welding is used, the flame of the blowpipe should be adjusted to show a slight excess of acetylene.

A fairly large tip or welding heat is desirable, and throughout it is essential to keep a large pool of molten metal. The welding rod must not be rubbed in the weld, but held under the surface of the molten pool, and the flame applied to melt the rod in the pool. When the level of the pool is sufficiently high, it can be melted into the base metal by directing the flame around the edges until the weld metal and the base metal flow together as a result of their own liquid state. Care should be taken, however, not to create so large a puddle that spilling over the edge on to the solid metal occurs, as this, while it gives an "adhesion," does not give a really permanent union.

Welding should be followed by a reheating of the whole casting to about 680° C. It should be held at this heat for roughly half an hour, and then quenched by plunging into lukewarm water. The most satisfactory result will be had by plunging the complete piece into a large vessel of water. Mere pouring of water on to the part will not suffice.

Manganese steel cannot be case-hardened. Quenched from 1,000° C. it has a tensile strength of about 65 tons per sq. in. Heated to 100° C. and pulled at that temperature, its tensile strength is about 70 tons per sq. in.; at 200° C., 65 tons per sq. in.; 300° C., 50 tons per sq. in.; 400° C., about 4 tons per sq. in. Of course, it will not stand such loads for long periods. At 400° C. some of the austenite is broken down to martensite, and the steel becomes harder when cooled, and is beginning to be slightly magnetic.

(*Continued on page* 176.)

Electric Resistance Alloys

The six underlying properties required of a high-temperature metal resistor are discussed by Mr. F. P. Peters, in a paper presented at the recent General Meeting of the Electro-chemical Society, in which he shows that of all alloys so far commercially produced, the 80-20 nickel-chromium alloy is superior.

THE toll which Nature exacts from materials at high temperatures is severe, and few metals or alloys are known which can fulfil her requirements. Briefly, the most important properties which a material must possess to be suitable for resistance-heating elements include the following :—

1. A conveniently high resistivity—*i.e.*, one that will permit the use of rod, wire, or strip of reasonable cross-section, with the standard voltages available, and the customary space considerations. This factor diminishes in importance as the material is increasingly capable of resisting oxidation. For example, platinum does not oxidise at any temperature below its melting point, and although it is a metal of relatively low resistivity, it would be ideal for heating element service, were it not so expensive.

2. A low temperature coefficient of resistivity, and one that is approximately constant from room to operating temperatures.

3. Resistance to oxidation and to scaling at temperatures up to 1,150° C. (2,100° F.). This is the prime requisite ; other properties may be lacking, but this ability to resist attack by oxygen at high temperatures is an essential characteristic of the material, unless, like molybdenum or tungsten, it is to be used in an inert or protective atmosphere of some kind. The mechanism of oxidation has been studied by various investigators and there has resulted a better understanding of the causes underlying oxidation, and the resistance of certain materials thereto.

4. A comparatively high melting point, and a narrow melting range. The resistor must not melt, nor commence to soften at the operating temperatures, which are thereby limited for any case to a maximum no closer than 150° C. to the melting point of the alloy. For service at 1,150° C., therefore, the only suitable materials are those of which the complete " freezing " points are higher than 1,300° C. This allows some service latitude in the event that overheating of the resistor, or fluctuation of the line voltage should occur.

5. Sufficient strength at high temperatures, the absence of pronounced grain growth, and absence of permanent increase in length.

6. Reasonable cost.

Early attacks on the problem of developing resistance materials produced a succession of alloys from nickel-silver to various steels, none of which was entirely satisfactory, until the development of nickel-chromium alloys for resistance heating. To-day, such alloys and their iron-containing modifications, by virtue of their peculiar suitability, have been accepted as standard for heating element service. Their position, however, is being attacked by iron base alloys, iron-chromium-aluminium and iron-chromium-aluminium-cobalt alloys. These alloys are higher in resistivity than the conventional nickel-chromium combinations, they have in some cases a lower temperature coefficient, and are often more resistant to oxidation and to scaling. However, their usefulness is markedly circumscribed by certain disadvantages, chiefly their permanent increase in length, and lack of strength at high temperatures, and the difficulty or impracticability of fabricating them successfully into perfect surface wire. At present it is doubtful that their challenge to nickel-chromium is a serious one, although the future may bring modifications in their compositions which will improve the mechanical properties.

Oxidation Resistance.

It is claimed that the most important property of a material for high temperature service is oxidation resistance, and Mr. Peters discussed this property. In the first place, he stated, all metals and alloys, with the exception of the noble metals (platinum, gold, and silver, for example), " oxidise " when heated in the air. In the case of the noble metals, no apparent oxidation occurs because the dissociation pressure of the oxide at any temperature is greater than the partial pressure of oxygen in the atmosphere in contact with the metal—*i.e.*, the oxide decomposes as fast as it is formed. Actually, with respect to oxidation, there are no chemically inert metals. All metals, even the noble metals, react with oxygen when heated in air, but the reaction is reversible, and the driving force at a given temperature is the relation between the partial pressure of atmospheric oxygen and the dissociation pressure of the oxide. The oxides of the base metals have negligible, almost infinitesimal, dissociation pressures, and are, therefore, most stable substances. These metals will, for this reason, be oxidised in varying degrees as they are heated in air to temperatures above 300° C.

Potassium
Barium
Calcium
Sodium
Magnesium
Aluminium
Manganese
Zinc
Chromium
Iron
Cobalt
Nickel
Tin
Lead
(HYDROGEN)
Copper
Silver
Mercury
Palladium
Platinum
Gold

The readiness with which a metal oxidises is roughly indicated by its position in the " electromotive series " of the metals, shown in accompanying table. Metals at the top are very readily oxidised ; those at the bottom, the noble metals, may not be oxidised at all on heating in air. A glance at this table will show that chromium should be quite readily oxidised, more so even than iron, and yet it is a fact that chromium is the one metal which is most frequently alloyed with iron to increase the resistance of the latter to oxidation. This paradox leads us to the most interesting phase of oxidation-resistance—the concept of " protectiveness."

The " protectiveness " of a metallic oxide may roughly be defined as its ability to obstruct the course of further oxidation, and especially to retard the rate of oxidation, whatever the nature of the heating may be, either continuous or intermittent. It has been shown that the abilityof an oxidisable *pure* metal to resist progressive oxidation is a function, not of any chemical property of the metal itself, but of the physical characteristics of the oxide formed. The base alloys can be divided into those which form oxides of the protective type, and those the oxides of which are porous, and do not at all impede further oxidation. In general, it may be said that the metals which form protective oxides are those whose oxides occupy a greater volume than the metal they replace.

Protective Oxides.

Actual calculation shows that among others, silicon, aluminium, zirconium, thorium, chromium, tungsten, iron, nickel, cobalt, and copper should form protective oxides, whereas lithium, sodium, potassium, magnesium, calcium, strontium, and barium should not. The figures

given, however, yield no exact indication as to the extent of the protectiveness; actually, the factors which determine the relative abilities of the protective oxide-forming elements to resist oxidation are not fully understood. We do know, however, that nickel is more resistant to oxidation than iron, and that a few per cent. of chromium, silicon, or aluminium, when added to either of them, may increase their oxidation resistance several hundred times because, as we believe, of the extremely great protectiveness of the oxides of chromium, silicon, or aluminium, as compared with those of nickel or iron.

While these laws, therefore, apply more specifically to pure metals, it is true that the properties of pure metals are in some degree conferred on alloys made of them. Thus it is that chromium inhibits the oxidation of iron when alloyed therewith, and, to a greater extent, of nickel. Chromium, itself, is oxidised quite readily, and the oxide formed tends to surround the unoxidised particles of iron and nickel, and protects these from oxidation. At the same time the chromium oxide formed, because of its greater volume, tends to "bridge" the particles, and so slows up the diffusion of oxygen to the inner surface of the metal.

Where intermittent heating is a part of the service requirements, as it almost always is, the resistance of the metal to scaling depends to a considerable extent on the coefficient of thermal expansion of the oxide. The closer the expansion coefficient of the oxide is in value to that of the alloy, the greater will be the resistance of the material to flaking or cracking during repeated heating or cooling operations. It is characteristic of nickel-chromium that the oxide formed possesses a coefficient of thermal expansion which approximates fairly well that of the alloy.

Service Comparisons.

Experience has shown that, in spite of the claims made for the iron-chromium-aluminium alloys, they do not stand up quite as well in service at 1,100° C. as do the nickel-chromium alloys, especially the 80 Ni, 20 Cr alloy. It is true that particular iron-base alloys of the type mentioned possess an equal or even greater resistance to oxidation, but their use should be confined to heat resistant members, or parts of apparatus which are well supported in service, and are not heated directly by the electric current. An unfortunate feature of these alloys is their excessive grain growth on prolonged use at high temperatures; in the case of resistance wire made of iron-chromium-aluminium alloys, this is manifested by a permanent increase in length of the element as time goes on, resulting in an increase in electrical resistance, a decrease in wattage, and, therefore, at constant voltage, a decrease in temperature of the unit. The growth of the grain also develops a brittleness in the iron-chromium-aluminium alloys discussed which becomes evident on cooling to room temperature. These factors, important as they are to the user of resistance wire, are not always considered when comparative life tests are made on heating element materials.

An unfortunate feature of the iron-chromium-aluminium alloys as compared to nickel-chromium alloys, stated Mr. Peters, is the lower strength at high temperature possessed by the former. In service this results in sagging whenever the element is not completely externally supported. Their greater strength at high temperatures is an outstanding characteristic of the nickel-chromium, as compared with other alloy combinations commercially available. At 1,100° C., for example, a chromium-iron-aluminium alloy will have a tensile strength not greater than 1,500 lb./sq. in. (105·5 kg./cm.²), whereas nickel-chromium, at the same temperature, may sustain a tension of over 6,000 lb./sq. in. (421·9 kg./cm.²) without breaking.

The presence of large amounts of aluminium in the iron-chromium-aluminium alloys, while largely responsible for their excellent oxidation resistance, reduces the ductility of the material to a very low figure. Thus, the elongation of the iron-chromium-aluminium-cobalt alloy, as delivered, averages 14% in 10 in. (25·4 cm.), whereas the elongation of annealed nickel-chromium alloy may be as high as 35%. For this reason these alloys are rather difficult to fabricate in the cold, and tend to become brittle if great care is not taken in all stages of their processing. Shapes are difficult to form, and helical coils made of such alloys do not possess the perfectly bright smooth surface, and the even "stretch" characteristic of nickel-chromium coils.

Mr. Peters made it clear that the foregoing statements were not meant to be a sweeping indictment of the iron-base chromium-aluminium alloys, with or without cobalt. On the contrary, these aluminium alloys constitute a most useful group, and should find wide application for (1) heating elements operating at temperatures above 1,200° C., where the cost of platinum would be prohibitive; (2) heat resistant applications not involving the passage of electric current through rod, wire, or strip of the material; and (3) resistance elements for low temperatures, that is, not used for heating purposes, where the high electrical resistance makes it possible for the equipment designer to conserve considerably in space. For most industrial and domestic heating applications, however, nickel-chromium, because of its excellent heat-resisting properties, its mechanical stability at high temperatures, and its general efficiency and convenience, should be found much more suitable.

Magnitogorsk Metal Plant Continues to Expand.

Extensive work is being carried out for the further expansion of the huge Magnitogorsk Metallurgical Plant, which for the last two years has occupied first place in the Soviet Union in respect of metal output. This year a third ore-crushing plant has been put into operation, and the construction of a second ore-washing and concentration plant is nearing completion. A sintering plant, with a daily output of 6,000 to 8,000 tons, is now under construction. A number of new departments have been opened in the coke plant, to treat the chemical products from all the nine-coke batteries of the metallurgical combine.

A large coal warehouse, with a ferro-concrete viaduct 1.5 kilometres long, and railway lines are now being built for the second section of the coke plant. Work has already commenced in the blast-furnace department for the construction of the fifth and sixth blast furnaces.

Four 165-ton furnaces commenced work in the open-hearth shop this year. One more furnace, the twelth and last in this shop, will soon be put into operation. The foundation for a second open-hearth shop has already been laid.

Two new rolling mills have been completed this year. Preparations are being made for the installation of a modern type of wire-drawing mill, with an annual output of 220,000 tons. This mill, which is being manufactured abroad, will be shipped this year. Another blooming mill is being produced for the combine by the Izhora Plant.

Seven school buildings accommodating 3,000 children have been constructed in the new town near the combine this year. The schools are faced with marble and are the most beautiful buildings in the town. A large club and theatre are being built. Five apartment houses were built before January, 1935, and the construction of another eight is nearing completion. A new settlement—Berezki—consisting of cottages for engineers and technicians, will be completed in the near future. Extensive work is being carried on along the right bank of the river, at the site of the new town, where water and sewage pipes are being laid.

We have received a copy of a new publication which gives a fully illustrated description of the Fraser and Chambers-Marshall wagon tipplers of the side discharge type, and shows a number of installations including a 60-ton tippler which will shortly be exported to the Lunghai Railway Co., China. Copies are available from The General Electric Co., Ltd., Magnet House, Kingsway, London, W.C. 2.

Copper Stools for Ingot Moulds

Experiments have shown that properly designed high-conductivity copper stools resist the cutting action of molten steel due to the rapidity with which the heat is withdrawn from the stool face. It is claimed that the life of the stool is greatly extended, the contour of the ingot butt remains flat and the temperature of the steel in the lower portion of the mould falls more rapidly.

ON the assumption that the high thermal conductivity of copper would permit of its use for moulds for casting steel ingots, laboratory tests made by casting 50 to 300 lb. ingots have shown that steel can be cast into such moulds without damage to the mould, that the ingot surface is better, and that a finer grain structure is formed, but only to a small depth. Satisfactory experimental work, however, requires large scale tests, and such investigations have been carried out by C. E. Williams and H. B. Kinnear* in several steel plants in the United States. So far, the work has been concentrated on the use of stools, inserts, and mould plugs, and over 500,000 lbs. of copper stools for ingot moulds are now being used by the American steel industry.

The melting point of copper is about 450° C. below the pouring temperature of steel and 65° C. below that of the cast iron used for moulds and stools, but the thermal conductivity of the copper is nine times that of the cast iron, and this greater thermal conductivity offsets the lower melting temperature through rapid heat conduction, with the result that the surface of a copper stool in contact with liquid or partially solidified steel is considerably cooler than the surface of a cast-iron stool. Comparative temperature readings taken at the top surfaces near the centre line of a copper and a cast-iron stool show the surface temperature after the first impingement of the metal stream to be about 425° C. lower in the copper stool. Ordinary cast-iron stools have an average life of appreciably less than 100 heats, and long before they are discarded, they are badly cut and deeply cracked, where the metal stream first strikes. Properly designed high-conductivity stools resist the cutting action of molten steel due to the rapidity with which the heat is withdrawn from the stool face. The life of the stool is greatly extended, the contour of the ingot butt remains flat, and the temperature of the steel in the lower section of the mould falls more rapidly with a consequent increase in the life of the mould.

Copper stools are cast either in sand moulds, in open moulds, or in vertical water-cooled moulds in the form of "cakes" of the required size and the copper used for their manufacture is "tough-pitch" copper with an oxygen content of approximately 0·04%. A large volume of copper is necessary to avoid overheating the surface of the stool and it is more effective to get increased weight by increasing the thickness, rather than the cross-sectional area, which need not be larger than the mould base. To avoid cutting and cracking of the stool, experience has shown that its weight should be at least two-thirds that of the ingot cast, and that the ratio of ingot bottom area to thickness of stool should be below 55 : 1. In the casting of low-carbon steels, copper stools, 10 to 12 in. thick, have proved satisfactory for ingots ranging from 20 by 20 in. to 30 by 30 in.

Copper stools develop hair-line thermal cracks, which should be peened as fast as they form; otherwise they gradually develop into fairly deep cracks, which allow of penetration of the liquid steel to such a depth as to cause sticking of the ingot. Large cracks are also occasionally developed across the centres of stools used with rectangular shaped moulds, the crack forming along the short axis due to the extreme stresses resulting from the heavy weight of the steel ingot and mould during the period when the stool is being heated, and the copper is in a weakened condition. The zones occupied by such cracks represent only a small part of the total area of the stool, but render it unfit for service. To minimise such failures, a laminated stool has been developed recently and consists of a number of cakes of copper held vertically in a cast-iron frame by means of a spring at one end. When cracks occur in any individual cake it is easily removed and replaced.

Copper stools, as a result of their cost, have to have a life six to eight times longer than that of cast iron. The first stool to be put into commercial use has been used for over 1,500 heats, 900 on one side and 600 on the other and is still in service. As far as it has been possible to determine, the use of copper stools has not adversely affected the quality of ingots, tests made on rimming-steel ingots cast on copper and iron stools giving similar results. Plant tests have also shown that the life of moulds is increased from 30 to over 100% when copper stools are used, and this is attributed to the more rapid abstraction of heat from the steel by the copper stool causing the steel in the lower section of the mould to cool more rapidly and to freeze earlier, and thus establish the gap between ingot and mould more quickly, and thereby to lower the surface temperature of the lower section of the mould.

Thermal conditions in both the stool and mould have been determined by actual measurements. Two tests were made, both with the same cast-iron mould, once on a cast-iron stool and once on a copper stool. In both cases 11,200 lb. of metal was poured at 1,565° C. and the temperatures determined by means of thermocouples inserted in the wall of the mould and the bottom of the stool. Comparison of the curves obtained for stool temperatures at the top and bottom surfaces near the centre line, near the outer area covered by the ingot and on the edge of the stool showed that after the first half hour all these different positions in the copper stool were within 15° C. of the same temperature at any moment, whereas with the cast-iron stool there was a 250° C. difference even after 105 minutes. Mould temperature curves at 2, 6, 14, 30 and 46 in. level above the mould bottom were closely identical for both types of stools throughout the upper levels and initially at all levels, but after a period of time the curves for the 2, 6, and 14 in. levels for the cast-iron-mould-copper stool arrangement fell below the curves for the cast-iron-mould-cast-iron-stool arrangement.

Experiments with small copper moulds up to 7-in. section indicate that a fairly long life may be expected, that no difficulties attend their use, and that there is some improvement in the ingot surface. Further work, however, is necessary on mould design and on the effect of copper moulds on the quality of the steel, but so far the success obtained with copper stools encourages the hope that such work will prove worth while.

*C. E. Williams and H. B. Kinnear, *Metals and Alloys*, 1935, Vol. 6, pp. 169–172 and 213–217.

The extent to which aluminium alloys are being applied as structural materials is indicated in a recent publication issued by the British Aluminium Co., Ltd., Adelaide House, King William Street, London, E.C. 4. It describes the manufacture in light aluminium alloys of structures which, following all precedent, would be of steel. Many readers will be surprised at the revolutionary changes being effected in structural work by means of light alloys and will find the descriptions and data given in this booklet both interesting and informative.

Reviews of Current Literature

Chemical Analysis of Aluminium.

The chemical analysis of aluminium and its alloys has become increasingly complex with the development of the alloys, and greater demands are being made on the analyst for speed in his analyses and accuracy in his results. Time is frequently an important factor, and the methods of analysis must be accurate enough for the work in hand, and yet be simple and rapid. This book presents methods for the chemical analysis of aluminium which are adopted by Aluminium Research Laboratories, Aluminium Company of America, and it will be a distinct advantage to workers in aluminium because we know of no other book on the chemical analyses which is devoted entirely to aluminium.

Chemical analysis is the most widely-used control applied to industrial processes and operations. It touches all the phases of the production and fabrication of such a metal as aluminium. In the production of ore, chemical analysis is the major control of mining operations. In ore processing, it not only evaluates raw materials, but controls step processes and products, and determines the purity of the product. It controls the raw materials used in the electrolytic process for the production of metal. By analysis of the metal produced it not only gives a check on the previous control, but also gives valuable information to the user of the metal. It controls remelting and alloying processes and serves the metallurgist in a variety of ways.

Methods for the analysis of aluminium and its alloys differ from methods used for other metals only in the preliminary steps of solution and separation; the actual determinations are, in general, the same. The present trend of analysis of aluminium is towards simpler control methods, and towards more refined methods for the determination of small amounts of various constituents occasionally introduced into aluminium, and this book will be found invaluable to the chemist and metallurgist who desires to apply the most modern methods for the analysis of this metal.

Prepared under the Direction of H. V. Churchill and R. W. Bridges; published by Aluminium Research Laboratories, Box 772, New Kensington, Pennsylvania, U.S.A. Price 50 cents post free.

Solder.

Designed to show the wide fields of application of solder, the methods of its use, and the way in which these methods have been adapted to serve the needs of present-day high-speed production, a booklet which is both interesting and informative. Solder has been used for such a long time that it has become a necessity, and we are apt to overlook its importance because of its general every-day use; yet modern life would be very different if the possibilities presented by solders were not available. Foodstuffs and a wide variety of other products are distributed to an increasing extent in hermetically-sealed containers, for the production of which solder is a necessary material. It is also essential in securing the effective distribution, use and disposal of water. In recent years the purity and humidity of the air have been brought under control to a remarkable degree by devices of engineering science in which solder is extensively utilised. In the progressive improvement of transport by means of the internal-combustion engine solder plays a vital part. The increasing applications of electric power, which are transforming modern life, are in almost all instances, dependent upon the use of solder. Indeed it would be difficult to determine any form of engineering in which solder does not play an important part.

Solder is not a specific substance, but comprises a whole series of alloys, the properties of which vary considerably with the composition. In this booklet the properties of the tin-lead alloys of the compositions in general use are treated. The book contains 54 pages; it is admirably illustrated, and is issued free by the International Tin Research and Development Council, Manfield House, 378, Strand, London, W.C. 2.

The Finishing of Zinc Alloy Die-Castings and Rolled Zinc.

The problem of plating rolled zinc and die-cast parts has been encountered by many metal finishers during recent years, and this booklet provides practical information designed to simplify the operations. The information given contains nothing new or revolutionary, but stress is laid on such facts as are of importance in the successful finishing of zinc parts. Pre-plating procedure, such as cleaning, acid-dip and rinsing, has been given particular attention, since successful finishing depends upon the efficacy of these processes.

The subjects discussed are polishing; cleaning; acid dip; rinsing; primary coating; plating time; nickel plating; nickel copper; copper nickel deposits; bright nickel deposits; secondary coatings; direct finishing; stripping methods; purification of solution; and measurement of thickness of coating. The information is presented in a very lucid form, and all interested should obtain a copy of this booklet, which is issued free by the Imperial Smelting Corporation, Ltd., 95, Gresham Street, London, E.C. 2.

Tungsten Plating.

DISCUSSING tungsten plating, W. A. Kœhler points ot thatu this metal is in the same series as chromium in the periodic system. It has a bright silvery lustre, but, unlike chromium, it is not attacked by any of the common mineral acids, although it can be dissolved by a mixture of nitric and hydrofluoric acids. A thick coating of metallic tungsten can be plated electrolytically, and is especially valuable for covering baser metals in laboratory ware. The metal is not affected by sulphur or phosphorus. It has a hardness on Moh's scale of about seven.

The tungsten plating solution is easy to prepare. A saturated solution of sodium carbonate is made at 100° C., and tungsten trioxide, WO_3, is added as long as the sodium tungstate formed is soluble. The solution is electrolysed, usually at 75 amperes per square foot, and the higher the temperature the brighter the deposit. The solution is not entirely stable, and will slowly deteriorate when used constantly. (*Journal of the Franklin Institute*, vol. 220, No. 1, July, 1935, p. 132.)

High-Manganese Steel.

(*Continued from page* 172.)

These properties may be affected to a greater degree according to the length of time that the steel is exposed to the temperature.

The drilling, turning, boring, planing and facing of manganese steel, once not commercial propositions, have now become commonplaces in machine-shops, and every manganese-steel manufacturer will provide full instructions on these operations, if desired. But there is one operation more difficult than any of these which is less familiar. This is the opening out of holes already in existence. The smaller the amount of material to be removed, the more difficult is, in general, the operation. Only drills specially designed for this work, usually with the corners bevelled off in order to present a more efficient cutting edge to the work, should be used, and these made from cobalt high-speed steel.

Electro-magnetic Equipment for the Metal Trades

By W. E. BOX*

With the increasing use of electricity resulting from the development of the grid system, this form of power is proving of great value in the metal trades and electro-magnetic appliances have been developed to simplify otherwise difficult operations. Some of these appliances are described in this article.

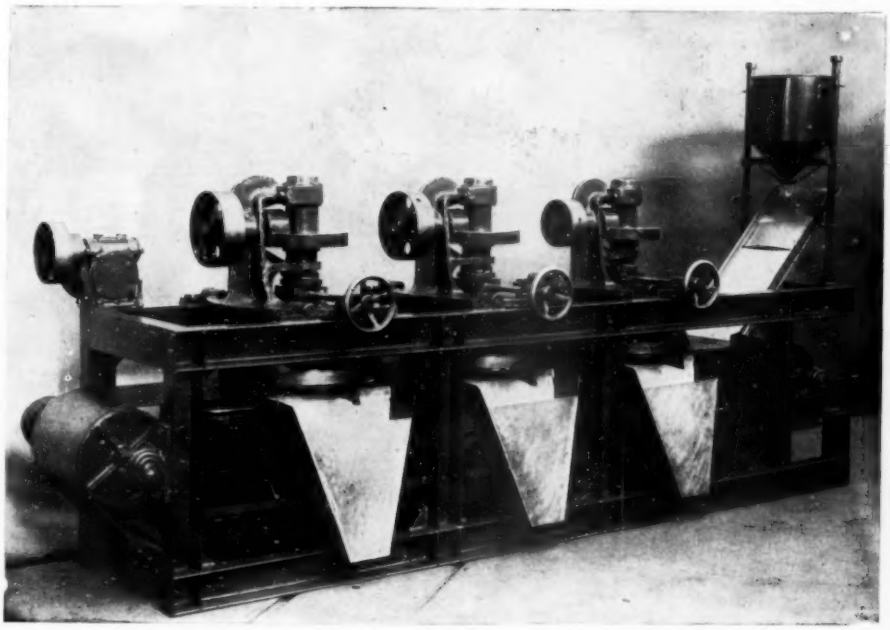


Fig. 2.—Triple disc pattern ore magnetic separator. In this separator micrometer adjustments are arranged for raising, lowering and tilting each disc.

NOW that the grid has made the supply of electricity easily available all over the country, the advantages of electro-magnetic appliances for various purposes in the manufacture of metals are being increasingly realised, but there are probably many in the metal trades who are not fully aware of the assistance they may obtain in this way.

Electro-magnetic equipments may roughly be divided into two classes, one magnets and machinery for separating ferrous or magnetic substances from the bulk of material, and the other, devices for producing powerful magnetic fields for holding or lifting or for exerting pressure in a clutch or brake.

Fig. 1.—Laboratory or prospector's magnet for testing ores, powders, etc.

The separating appliances are those most used in the non-ferrous metal trade. Starting at at the ore stage, there are many ores that are feebly magnetic, and a handy prospector's or laboratory magnet, Fig. 1, is made for testing these in which the poles of a powerful electro-magnet are arranged over a plate on which specimens of the powdered ore are spread. The plate is adjustable so that it can be moved nearer to or further from the magnetic field. The magnet attracts the magnetic portions of the ore from the bulk of the sample, so that an estimate can be made of the richness of the ore.

Generally, there is more than one metallic compound in the ores as mined, and as these vary in the degree to which they are magnetic, this variation is used to separate them. This is done in the laboratory testing magnet by gradually adjusting the plate on which the powdered ore is spread nearer to the magnet pole. The most magnetic particles are attracted while the plate is at a distance. These are wiped off the poles, and the plate adjusted nearer when the next strongest magnetic dust is drawn on to the poles, the process being repeated according to the number of metallic ores in the sample.

For treating ores on a large scale for manufacturing purposes, the firm have designed a triple disc pattern ore-separator, Fig. 2, in which the varying magnetic intensities of the different components of the ore are taken advantage of, to separate them from each other, as well as to extract them from the tailings. The powdered ore is fed from a hopper by a distributing chute evenly over the surface of a conveyor band. This band passes under the faces of three steel discs mounted one behind the other on vertical spindles, so that they revolve just over the band. The edges of the bottom faces of these discs are formed into specially-shaped crown teeth which come fairly close to the band. Under the band there are fixed electro-magnets under the front and back edge of each disc, and these, by induction, make the teeth of the discs into magnetic poles which attract the magnetic particles of the ore as it passes under them. The magnetic field of each edge of the discs can be controlled by the fixed magnet under it and also by its distance from the magnet which is operated by a micrometer adjustment to the bearings of each disc.

The discs are given a slight tilt, so that the back edge is slightly further from the band than the front. By using all these controls, the ore is made to pass under six magnetic fields, each gradually increasing in strength, and the most highly magnetic portion of the ore is attracted on to the

* Managing Director, Electromagnets, Ltd.

Fig. 3.—Scrap sorter of the bench type for detecting hidden iron and "irony-brass."

teeth at the front of the first disc and the less magnetic particles in turn as they pass under the stronger magnet poles.

The edges of the disc overlap the band at each side, and the teeth being then outside the magnetic field, allow the particles of ore to be wiped off and fall into their appropriate receptacles.

The machine is of all-steel construction of ample strength. It is operated by one countershaft, the band and discs being operated by enclosed gear units, well lubricated.

Fig. 4.—Small chute magnet for dealing with small scrap, casters ashes, enamel and glaze, etc. It is fitted with adjustable and removable inductifier bars arranged for mechanically-controlling the magnetic intensity.

In most non-ferrous metal works, scrap plays a most important part, and it is usually essential that before being used it should be free from iron and steel. For this purpose many types of appliances have been designed to meet varying conditions. The simplest is perhaps the hand magnet with double poles which can be connected by a flexible lead to a wall-plug for current supply.

By passing the poles through small parcels of swarfe, which should be suitably spread out, any iron or steel parts can be detected and drawn out, the magnetic attraction of the poles being of course infinitely greater than in the old horseshoe fixed magnet used in the old days. For bigger quantities of scrap, a suspension magnet, much larger and more powerful, can be slung by a chain over benches for treating larger pieces of non-ferrous scrap, and is used for detecting taps, drills, etc., which may be broken in the metal, and not visible.

Another type is what is called a bench sorter, Fig. 3; this is mounted on the side of the scrap sorter's bench, and as he passes pieces of scrap over it he can feel if there

Fig. 5.—Jig-shaker separator for treating metal residues and powders as used for refiners generally.

is any iron or steel in them by the magnetic pull which the poles give. This bench magnet is fitted with adjustable and different shaped poles to give varying fields to suit different types of scrap.

For dealing with scrap metal in bulk and not by hand there are chute, drum and conveyer pulley types of apparatus.

The magnetic chute, Fig. 4, consists of a trough fixed on the incline down which the material travels, passing over a number of magnetic poles which retain any ferrous material whilst the remainder passes on. Stationary chutes are made for dealing with metal that will gravitate without clogging or bridging down an angle not exceeding 60° from the horizontal. These are hand-fed, and there are gravity-loaded induction baffle plates to regulate the flow of small material. Should the current fail, an electrically-operated diverting chute automatically comes into play and prevents any material that has not been cleaned from passing into the container of cleaned material.

For materials that will not gravitate freely down the

chute by their own weight, there is a vibratory type chute magnet, which is carried on spiral springs and vibrated by means of a shaft carrying an unbalanced pulley, and another new development of this type of separator is the jig-shaker pattern, Fig. 5, recently designed, in which the chute alone is agitated. The magnetic portion is stationary in a magnet box under the bottom plate of the chute. The chute itself is agitated by an eccentric on a side-shaft actuated by a special bevel gear which allows the chute to be adjusted to different angles of inclination, so that the best rate of descent can be arranged for any particular type of material.

These vibratory and jig-shaker chutes are fitted with the electrically-operated fool-proof collapsible bridge which cuts off the flow of unclean material if the current fails.

The rotary drum separator, Fig. 6, is probably the most generally-known type of electro-magnetic machinery. It consists of a drum with electro-magnets inside, so that magnetic poles are formed across sections of its circumference. The materials to be cleaned are fed on to the top of the drum, and as it revolves slowly, the ferrous particles in it are attracted by the magnetic poles, and are carried round under the drum to the back, whilst the rest of the material drops off at the front. The unit is of half-moon shape, magnetising the front half only, and the iron and steel pieces are automatically released into a separate container. A hopper with a jig-shaker feed tray is often used with these rotary drum separators, giving a regular feed of the material on to the drum, which is always an essential feature where high efficiency is desired.

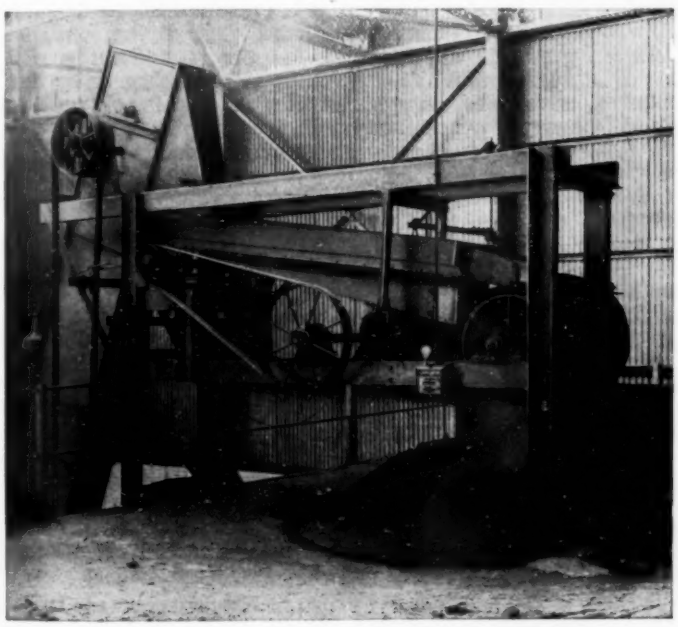


Fig. 6.—Drum separator incorporating vibratory screens for sifting and separating swarfe, foundry sand, etc.

Of late years the mechanical handling of materials is more generally called for, and the pulleys shown in Fig. 7 are designed for use in conjunction with band conveyers. Electro-magnetic pulleys are, of course, no new thing. In the usual form of a pulley the magnetic poles are concentrated in two or more strips running round the centre and edges of the pulley. This leaves neutral or feebly-magnetic zones between the poles, and it is possible that ferrous material passing over these zones may fail to be attracted, and not be separated out. The pulley illustrated has been designed to remedy this defect. It has a series of magnetic barrages which run right across at right angles to the direction of travel, so spaced that material on the conveyer band passing over the pulley is bound to pass through one or more of these barrages, and is held against the conveyer band by magnetic attraction, whilst the non-ferrous material falls off. The ferrous particles are carried under the pulley and drop off into a separate receptacle as the return band passes away from the periphery.

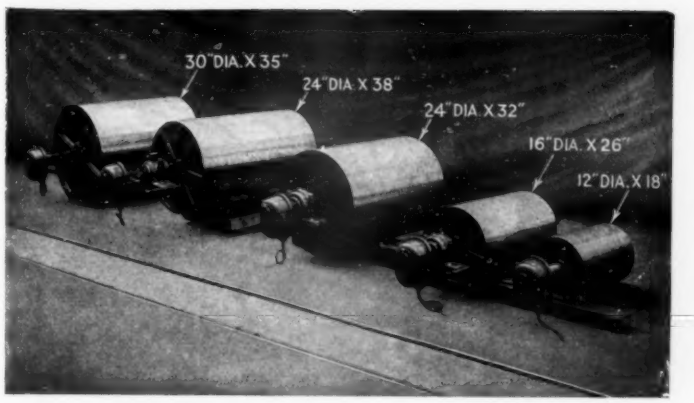
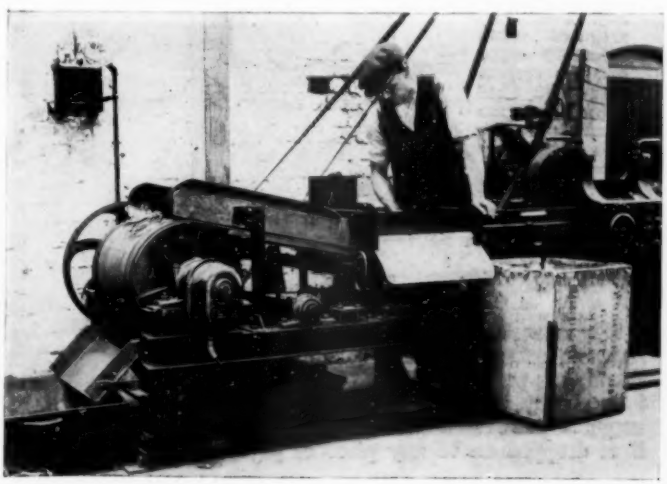


Fig. 7.—Magnetic pulleys for band conveyers, designed to deal with ore, foundry sand, cement, etc.

A number of plants incorporating this type of pulley are made to meet the wants of special trades. One is a universal pattern separator, Fig. 8, which consists of a hopper which feeds the material on to an endless band. There is a feed-regulating gate which determines the distribution of the material on the band which travels over the pulley where the ferric content of the material is extracted and discharged separately.

The collector gear of the pulley is totally protected, and the whole installation is mounted on a steel framework of rigid design. This can be used for small mixed scrap or swarfe by the non-ferrous metal user, and has also been found useful for the treatment of ores, etc. Other forms of separators are made for taking out tramp iron in the form of nuts, bolts, nails, etc., where it is desirable to protect crushers, grinders and pulverisers. In the iron foundry, the use of the electro-magnetic

Fig. 8.—Universal type separator for treating sintered ores, swarfe, and small mixed scrap.



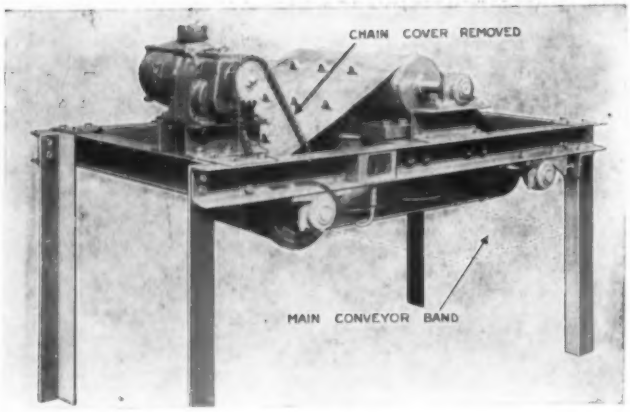


Fig. 9.—"Overband" separator for extracting tramp iron from material passing underneath on conveyer bands.

pulley and drums in the sand-handling and conditioning plant gives a big saving and considerable improvement in the quality of the sand, as all spillings, brads, gits and other bits of iron can be extracted from the old sand before it goes to the sifting and milling processes, and its use is likely to be universal in all iron and steel foundries.

Another type of separator for dealing with material on band conveyers is what is known as the "Overband" separator, Fig. 9. This consists of a short band with steel studs which is made to pass over the band conveying the material at right angles to it.

Fig. 10.—Circular lifting magnets for handling scrap pig iron, etc.

The steel studs on the band are made powerfully magnetic as they pass over the conveyer band, by induction from fixed electro-magnets arranged at the back of the band, and they attract the ferrous content of the material on the main conveyer band as it passes under them, carrying to the side of the main conveyer band where the studs become demagnetised, and release the separated iron and steel pieces into an appropriate side chute.

Fig. 11.—Special magnet with adjustable centre pole for suspension over inclined band conveyers handling scrap, fuel, rock, etc.

The second class of electro-magnetic appliances are magnets generally of a larger and more powerful type. For lifting purposes the circular lifting magnet, Fig. 10, is probably the best known, and consists of powerful magnetic poles enclosed in a circular case. Slung on a chain it is dropped on to any piece of pig-iron, iron or steel scrap, skull cracker balls, ingot moulds, etc., and the current being switched on the magnetic attraction holds the article to be lifted without any need of fastening in any way.

Other shapes include rectangular magnets for handling sheets, tanks and light structures. Two or more can be used with spreader beams for handling long bars, tubes, etc. A special tripolar magnet, Fig. 11, consists of a magnet with two end poles and a third one between them which is adjustable. This can not only be used for lifting sections such as girders, channels, rails, etc., but also can be suspended over conveyor bands, etc. for extracting any tramp iron or other ferrous content of the material being conveyed.

Magnets are available for holding plates to be sheared, and this application is rapidly gaining favour as the work has only to be placed in position and the current switched on for it to be held securely whilst any adjustment can easily be made when the current is switched off.

For power transmission, particularly where electric motors are in use, electro-magnetic clutches are found to have great advantages as they are instantaneous in action, and can be easily incorporated in the design for speed-reduction gears, power transmission, etc.; one particular application is on the screw-down gear for rolling mills. In conjunction with clutches, or by themselves, electro-magnetic brakes are now largely used, and many types are now made, including band, clapper, disc designs, etc., to any industrial purpose.

The Institute of Metals.

Programme for Winter Session.

A FULL programme for the coming session has been planned by the Institute of Metals and its several local sections. Issued in the form of a folder, the programme includes a separate page devoted to the activities of each section. These branches exist in all the principal non-ferrous metallurgical centres throughout the British Isles. Though not a section of the Institute of Metals, the Manchester Metallurgical Society is in association with the Institute, and its programme, for the first time, is included in the folder, since members of the Institute of Metals are now eligible to attend meetings of the Manchester Metallurgical Society as well as of the various local sections.

The meetings of the parent body are shown to be three in number for 1936. The twenty-eighth Annual General Meeting will be held in London on March 11 and 12. On May 6 the twenty-sixth annual May lecture is to be given in the hall of the Institution of Mechanical Engineers. In September, Paris will be the scene of the Twenty-eighth Annual Autumn Meeting. This will be the first occasion on which the Institute of Metals has held a meeting in France.

The programmes of each of the local sections—which include more than 40 papers and several visits to works—are comprehensive in their appeal. Thus, in Glasgow, a paper will be read on "Corrosion of Metals by Industrial Waters"; Sheffield will be informed with regard to "Rolled Gold and Its Industrial Application" and "The Adhesion of Electro-deposited Nickel." Birmingham is naturally interested in such subjects as "The Production and Control of Bronze Castings" and "The Hot Rolling of Sheets." London is fortunate in having secured Professor E. N. da C. Andrade to lecture on "The Ultimate Strength of Metals," whilst Mr. G. S. W. Marlow is to present to this section a paper on "Patent Law—With Special Reference to Non-ferrous Metals." Membership of the sections is free to all members of the Institute, and visitors are invited to attend the meetings, particulars of which can be obtained from the Secretary, Mr. G. Shaw Scott, M.Sc., 36, Victoria Street, London, S.W. 1.

Petrol from Coal

The great coal-hydrogenation petrol plant of Imperial Chemical Industries, Ltd., is the first in the world to make petrol on a commercial scale by this process. The raw materials are coal and water, and in this article the chemistry of the process is briefly discussed.

THE opening of the coal hydrogenation petrol plant of Imperial Chemical Industries, at Billingham-on-Tees, by Mr. Ramsay MacDonald marks an important event in the industrial progress of the United Kingdom. This plant is the first in the world to make petrol on a commercial scale by the hydrogenation of bituminous coal. A pilot unit which treated 15 tons of coal a day was worked in Billingham in 1930 and 1931. The only other commercial scale plant are at the Leuna works of the I.G. in Germany, where 300,000 tons per year of petrol are made from brown coal or lignite, and Standard Oil Company's plants in America using petroleum oil as a raw material.

Research work by I.C.I. has been continuous since 1927. In 1931 an agreement was made with the other operators in the hydrogenation field, the I.G. of Germany, the Standard Oil Company of New Jersey, and the Royal-Dutch-Shell Company, resulting in the formation of the International Hydrogenation Patents Company to pool patent rights and to exchange technical information. Arrangements were made at the same time for marketing production through existing oil companies. In 1933, the Government announced the British Hydrocarbon Oils Production Bill, which guaranteed a preference on home produced light oils for a period of years. The period from April, 1935, is 4½ years if the preference remains at the present figure of 8d. a gallon, 9 years if the preference drops to the guaranteed minimum of 4d. a gallon, and in proportion for other amounts of preference. The plant at Billingham was authorised immediately and construction started in August, 1933. It was originally intended to produce 100,000 tons a year of petrol from coal. It was later decided to increase the capacity to 150,000 tons a year of petrol, the extra 50,000 tons to be made either from coal or creosote oil and low-temperature tar. The first section was ready in January, 1935. Creosote oil was used as the starting material, and the first petrol was made in February. The first coal unit was started in June, and the output is expected to reach the designed figure before the end of this year. The normal rate of production is 410 tons or 123,000 gallons of petrol a day.

The hydrogenation process is a revolution in fuel technology. The hydrogenation of coal is a self-contained process as the only raw materials are coal and water, and, if desired, petrol can be the sole end product. Flexibility is a valuable feature as tars and petroleum can be treated and the conditions arranged to give fuel oil, Diesel oil, petrol and liquefiable hydrocarbon gases such as propane and butane. Hydrogenation makes it technically possible to render this country independent of imported oil supplies (with the exception, at present, of lubricating oil). It is a great technical advantage to operate in units of a size comparable with those in the Billingham plant, because of the complicated nature of the process. Although the unit size is large and the capital cost correspondingly high, this cost compares favourably with that of other methods of making oil from coal, when calculated on the basis of liquid fuel output. The Billingham plant makes only 4% of the country's consumption of petrol, but its output is nearly as large as that of all the other home sources of motor spirit from coal added together, such as benzol from gasworks and coke ovens, low-temperature carbonisation and so on.

The Chemistry of the Process.

Petrol contains 85% carbon and 15% hydrogen, whereas in coal 85 parts of carbon are associated with only 5 parts of hydrogen. In the hydrogenation process coal is treated under pressure with hydrogen, so that solid coal is transformed nearly quantitatively into petrol and gaseous hydrocarbons. The yield of petrol is between 60 and 70% by weight. Low temperature tar and creosote oil contain between 85% and 90% of carbon and between 7 and 8% of hydrogen. They can be hydrogenated into petrol with a yield of between 80% and 90%. The hydrogen is made by the decomposition of steam by means either of coke or the residual hydrocarbon gases from the process.

Description of Process.

The raw coal is cleaned to less than 2½% of ash and is ground up with oil previously made in the process to make a 50% coal-in-oil "paste. This is injected against the working pressure of 250 atmospheres (3,700 lb. per sq. in.) and mixed with hydrogen. The mixture is heated up to reaction temperature, and liquefaction of coal takes place at 450° C. (850° F.) and 250 atmospheres pressure. A

High-pressure vessels, termed 'converters,' where the coal is hydrogenated.

small heavy oil fraction containing the unconverted coal (5% by weight) and ash is treated for oil recovery and the coke residue is used as a fuel. The major part of the coal is transformed into lighter oils which are vapourised, and are recovered on cooling the gaseous products leaving the converters. The crude oil so obtained is distilled into heavy oil, middle oil and petrol. Heavy oil is further hydrogenated, in plant exactly similar to that used for the hydrogenation of coal, to give middle oil and petrol. Middle oil resulting from these two steps is further hydrogenated in vapour phase converters, in which the vapourised light oil and hydrogen are passed over a solid catalyst. The crude vapour phase product is distilled, the residual middle oil being separated from petrol and treated again. The whole of the coal is thus transformed into a small solid consumable residue, gas, and petrol.

Creosote oil and low-temperature tars are either employed for making up the coal paste or distilled and the fractions introduced into the liquid or vapour phase stages as appropriate. These materials play no essential part in the main process of making oil from coal, but are conveniently treated along with the coal. The final petrol, after a simple

purification, is pumped to storage tanks beside the River Tees from which it is shipped by steamers.

The plant took about eighteen months to build, and except for a few special instruments the whole was made in the United Kingdom. Special materials, never before employed in this country, were used. The steel industry deserves great credit for the successful production of plant from these special steels, particularly when the size and weight of the high pressure portions are considered. A large amount of special machinery has been employed, and throughout the workmanship of the contractors has been of the highest class.

"Hiduminium" 72.

The above alloy has been developed to supply a demand for an aluminium alloy which, after only one heat-treatment, will attain properties superior to Hiduminium Du Brand. The heat-treatment of this alloy consists in soaking for a suitable period at 500° C., followed by a quench in cold water. Maximum properties are attained after an ageing period of four to five days without further heat-treatment. It should be noted, however, that these remarks apply only to extruded, drawn and rolled forms of this alloy, and that in the forged and stamped conditions its properties, even after heat-treatment, are only equal to Hiduminium Du Brand.

Tensile Properties of "Hiduminium" 72.

Minimum Specification Figures.

Form.	0.1% Proof Stress, Tons per sq. in.	Ult. Stress Tons per sq. in.	Elongation % on 2-in. G.L.	Brinell Hardness No.
Extruded Bars and Sections	18	28	15	129—148
Solid Drawn Tubes ..	22	29	Not called for in Tube Specifications	129—148
Rolled Sheet	18	28	15	129—148
Forged Bar, as Spec. 4 LI.	15	25	15	110—130

Welding Aluminium.

A Coventry engineer is claimed to have perfected a process for the jointing of light aluminium alloys, such as RR 56, Duralumin, and the like. As is well known, efforts to weld these alloys in the ordinary way destroyed the effects of heat-treatment. The new welding material, known as "Alusol," is stated to be capable of joining the aluminium in cast, rolled, sheet, or tube form, and it fluxes freely at 200° C. Test-pieces of RR 56 and Hiduminum tubing, socketed one into the other, and joined with Alusol, were pulled apart at 26 tons per square inch, leaving the joint intact. It is also claimed that Alusol withstands corrosion well and is unaffected by ageing. The new process promises to be applicable in aircraft and automobile construction.

The process is analogous to soldering, except that no flux is required. The surfaces of the joint are first cleaned, oil being the chief thing to avoid, and the parts are placed in a heating device. After each part warms up, the end of a stick of joining material is rubbed on, and when it becomes hot enough the stick crumbles, a steel scraper being used to rub the material over the surface. When both surfaces are properly coated with the joining material they are brought together, heated again, and, finally, allowed to cool off. The process is applicable to joining aluminium tubing to steel, if the steel bracket is first tinned with soft solder; a joint of this character is said to withstand a pull of approximately 6 tons per square inch.

Hot Galvanising.

THE term galvanising is usually understood to apply to the "hot" galvanising process in which the articles to be treated are immersed in a bath of molten zinc. The process is probably more generally employed than any other as a protection for iron and steel against oxidation. As is well known, the rate of corrosion of an iron or steel surface depends upon the conditions to which it is subjected, and may vary very widely but for structural work the hot galvanising of the parts has proved a successful protection, and is widely applied. This process is distinct from the electro-galvanic method in which a thin coating of zinc is deposited by the action of an electric current.

Hot galvanising, when properly carried out, results in the production of an even, substantial and homogeneous coating which is corrosion-resisting, pliable, and firmly adherent to the iron or steel base. The anti-corrosive action of galvanised coatings depends entirely on their weather-resisting properties. When properly deposited, these coatings hermetically seal the surface and completely prevent the access of air to the underlying iron or steel. The practice of coating iron with zinc has, therefore, nothing to do with the relative electrolytic properties of zinc and iron, but is based on the fact that zinc itself is a highly weatherproof metal. After a short exposure to the atmosphere, zinc becomes coated with an extremely dense and insoluble coating of zinc oxide and basic zinc carbonate, which itself protects the underlying zinc from the further action of atmospheric agencies.

Thick Coatings.

The hot-dipping process applies relatively thick coatings of zinc, and is particularly suitable for withstanding outdoor corrosion. An iron container is used, containing molten zinc kept at about 450° C. The temperature depends on the nature of the material to be coated, for the higher the temperature, the greater is the solvent action of the molten zinc on the walls of the container, and the greater is its alloying action at the surface of the iron articles being dipped. The surface of the molten zinc is covered with flux, which consists of ammonium chloride with some tallow and occasionally glycerol. The flux cleans the metal, removes moisture, and prevents oxidation of the surface layer of zinc.

A dross, consisting of an iron-zinc alloy, gradually accumulates in the bath, and is removed at intervals. In many cases lead is added to the bath: it forms a separate liquid layer at the bottom and provides a cushion on which the dross floats, so facilitating its removal; lead also has the effect of preventing the overheating of the bottom of the container and diminishing the attack of the molten zinc on the iron. Aluminium in the form of an aluminium-zinc alloy is sometimes added. It makes the contents of the bath more fluid and provides a thinner and more uniform coating, and is therefore particularly useful when the articles to be coated are of very irregular shape or contain crevices. The addition of 1% of tin increases the uniformity of the coating.

The structure of the coating is by no means simple, for it consists of at least two and sometimes three distinct layers. Next to the base metal, there is a layer consisting mainly of the inter-metallic compound $FeZn_3$, then comes an intermediate layer, consisting largely of the compound $FeZn_7$, and the outer layer is mainly zinc, saturated with iron. The alloy layer is particularly thick when the dipping is carried out slowly. The alloys are anodic to iron, and therefore assist in protecting the base metal, but in this respect they are inferior to pure zinc.

The hot galvanising process is one of the most economical and effective methods for protecting iron and steel from corrosion and has very wide applications. Perhaps the most interesting use of this process is the transmission towers adopted by the Central Electricity Board for the "Grid" scheme.

The Testing of Engineering Materials

Some aspects of the testing of engineering materials were discussed by Dr. H. J. Gough and Mr. Clenshaw at a recent meeting of the Institute of Marine Engineers. Attention was directed to recently completed researches carried out at the National Physical Laboratory In each aspect covered, reference is made to some practical problems which appear to require future research, reference to which is given in this article.

MODERN developments in power plant and chemical plant have created an urgent demand for materials capable of withstanding extremely severe conditions of high temperature and stress. The essential problem arises, of course, from the tendency of metals to behave at elevated temperatures in a quasi-viscous manner, and deform continuously for extremely lengthy periods under stresses far inferior to that producing fracture, or even measurable extension, at atmospheric temperature; this property is commonly termed "creep." The present-day problem is not so much to guard against actual fracture or, on the other hand, to ensure entire freedom from distortion, but rather to be able to design so that the total deformation occurring within the required service life of the component shall not exceed permissible limits. For example, in turbine blading a limiting maximum extension, rather than a total absence of permanent deformation, is the practical requirement, for the latter may be impossible of attainment under service conditions: it has yet to be established that metals under operating conditions deform for a certain period only after which no further distortion takes place.

Reviewing, broadly, the present state of knowledge of the subject of deformation, it is clear that, primarily due to the pressing demands of industry for information concerning the properties of suitable materials for design purposes, major attention has hitherto been paid in research laboratories to the accumulation of what can only be regarded as test data; valuable though these are, a wide and attractive field remains to be explored in the study of the more fundamental characteristics of the deformation of metals by "creep."

High-Tensile Structural Steels.

As the result of extensive experience of service behaviour, engineers have acquired a great faith in the use of a sound, mild steel for structural work of all kinds, and until comparatively recently the employment of a high-tensile steel for this purpose has been regarded with the gravest suspicion in this country. But the need for greater economy in the design of large structures has acted as a special incentive to manufacturers to produce other materials. Some of these new materials have, in the last two years, been entrusted to the N.P.L. for thorough investigation of their mechanical properties. On considering the programme of tests to be adopted, it was concluded that the usual tests —as usually laid down in specifications—were not adequate to reveal data concerning some aspects of the general problem on which engineers would require assurance; accordingly, a related series of special tests was devised, and it is now our practice to apply these to this class of material. The complete scheme of tests is summarised as follows:—

1. Tensile tests in accordance with B.S.S. No. 15—1930.
2. Determination of tensile limit of proportionality and yield point.
3. Bend tests in accordance with B.S.S. No. 15—1930.
4. Rivet tests in accordance with B.S.S. No. 15—1930, also tensile tests on specimens machined from the rivets.
5. Notched-bar impact (Izod) tests.
6. Determination of complete tensile load-elongation curve, using a Dalby autographic recorder.
7. Examination of the effect of repeated tensile overstraining, using a Dalby recorder.
8. Determination of limiting range of repeated plane-bending stresses, using:—
   (*a*) Rectangular plates with original rolled surface;
   (*b*) Rectangular plates with machined and polished surface;
   (*c*) Rectangular plates with original rolled surface and containing drilled holes.
9. Determination of limiting range of reversed bending stresses (rotating bar machine), using:—
   (*a*) Polished specimens;
   (*b*) Polished specimens containing small semi-circular grooves.

It is the N.P.L. practice to make these tests on the high-tensile steel under investigation, also an exactly similar set on a standard mild steel, for purposes of comparison. An investigation of this type has been made on "Chromador" steel, on behalf of Messrs. Dorman, Long and Co., Ltd., and Fig. 1 shows the typical autographic records of the

Diagram Showing Complete Tensile Curves and Results of Overstrain Tests.

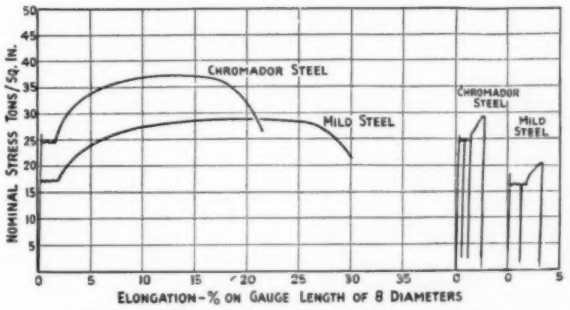


Fig. 1.—Autographic tensile stress-strain records.

tensile nominal stress-strain relations of the two materials, and the records of the tensile over-straining experiments. All the static tests reveal the excellent ductility of the Chromador steel, while the results of the impact tests exhibit good shock-resisting properties. Especially interesting and important features of the fatigue results lie in the disclosure that fatigue resistance of the high-tensile steel is not affected either by the condition of the rolled surface or by stress concentrations, or by a combination of these two, to a greater degree than the mild steel.

Lifting Gear Components.

What may be generally classed as "lifting operations"—the loading and unloading of ships and craft, and of material in building and constructional work, haulage in mines and quarries, movement of machinery and prime movers in workshops, for assembly, inspection, or repair purposes, etc.—are liable to involve considerable risk of injury to the personnel engaged and the valuable products concerned. Many interesting problems arise in connection with the lifting ropes, chains, and their terminal fittings. Some of these problems are of special interest in connection with the testing aspect, and merit brief mention.

One of the earlier researches at the N.P.L. was concerned with the causes of the brittle failure in service of wrought-iron chains and cables which had, hitherto, presented a baffling problem. It was clearly shown that failure was due to a "skin" effect caused by surface hardening, resulting

from impacts endured in inter-link action, hammering on ground, rattling through hawse-pipes, battering on chain wheels, cleaning in rumbling machines, etc.; it was astonishing to find that the responsible surface layer was extremely thin—thicknesses of a few thousandths of an inch only in many cases. The value of a shock test—tensile impact being especially suitable—in the testing of suspected cable, emerged clearly; this form of test had not hitherto been employed either in service or the laboratory. The same method was found to possess great value in an investigation which was made to assess the liability of chain and cable to behave in a brittle manner at moderately low temperatures. It was established that carefully prepared specimens of wrought iron do *not* develop temperature brittleness even at −78° C. On the other hand, both new and worn chains may behave in an extremely brittle manner even at ordinary frost temperatures as encountered in this country; failure occurs at irregularities of section, or where surface damage has occurred, owing to misuse in service, the responsible influence being "temperature-notched brittleness" to which wrought iron is susceptible. Again, brittle failures in service of wrought-iron components often reveal a curious laminated appearance, the fracture consisting of alternate layers of ductile and brittle material. It was established that the cause of the defective layers—whose brittleness is due to a high phosphorus and silicon content—can be traced back to defective puddling; subsequent heat-treatment cannot remedy the defect. This problem was solved when it was possible to make tensile and impact tests on small specimens cut from defective layers.

Commenting on the future of lifting chain, the authors state that there is no doubt chain will continue to be extensively used for lifting and other purposes; for many purposes its chief rival—wire rope—possesses grave disadvantages. Up to the present chain has mainly been made of wrought iron, prepared by a hand-forging process. Future developments, however, appear to lie in other directions. With regard to large studded cables for anchors, moorings, and similar purposes, excellent results are now being obtained by the electrically heated pressure-welded process developed in this country by Messrs. Samuel Taylor and Sons, Ltd.

An equally attractive future field of development appears to lie in the electrically welded, short-link steel chain. At present this industry has been rejected in this country, although considerable success is being obtained in America and certain Continental countries. An extensive series of tests is in progress at the N.P.L. on representative samples of electrically welded chains obtained from abroad, from some of which excellent results are being obtained; others are decidedly unsatisfactory.

Contact Corrosion

When two metal surfaces are in contact and subjected to vibration, an accelerated form of corrosion is liable to occur. This is a practical problem, examples of which are encountered in practically every branch of engineering, yet, curiously, it has hitherto received little special study. Components of machines that are firmly assembled, apparently beyond the possibility of any relative movement, and therefore of ordinary wear, are commonly found to have their mating surfaces corroded. In the case of steel, the surfaces are found to have become cemented together by relatively large quantities of oxide, are often badly pitted, and often damaged to such an extent that reassembly is impossible and replacement becomes essential. Serious trouble due to this cause has been brought to the attention of the N.P.L. in such cases as seatings of shafts on which couplings or gear pinions have been pressed, in the bosses of air-screws, etc. The "seizing" of nuts, the pitting of ball and roller bearings, and the "staining" of micrometer anvils are everyday examples familiar to all. It is a peculiar feature of the phenomenon that the most highly finished surfaces and the best types of fit appear to be most susceptible to this trouble; it is not corrosion of the usual type, as the oxide is produced copiously on surfaces which are totally immersed in oil. Pure rolling conditions do not usually produce this form of "rusting"; sliding or relative tangential motion is the ideal condition, according to an earlier N.P.L. experimental investigation.

Recently it was decided to resume the study of contact corrosion under conditions more resembling those occurring in engineering practice, and research on these lines is now in progress at the N.P.L.; some results have already been obtained which possess considerable interest. The optimum condition for contact corrosion is when two surfaces are pressed together under a steady normal pressure and then subjected to repeated relative tangential stresses (or strains). It was decided to commence by a study of various steel surfaces under these conditions, and a special apparatus was designed and constructed.

Experiments have been made with three types of steel, viz., hardened and tempered tool steel, "stainless" steel, and mild steel, and with combinations of these materials. Tests have also been made with a soft metal in contact with the hardened steel. The most important result so far obtained is the definite establishment of the fact that there is a marked difference in the rate of corrosion according to whether the surfaces are subjected to slight positive relative motion or not. Whenever a minute amount of slip is permitted, even if it is only a few millionths of an inch, rapid corrosion of the surfaces, with the formation of oxide debris, always results, whether they are clean or oiled. Soft brass is found to cause pitting and oxidation of a hardened steel surface; stainless steel also shows a strong tendency to seize, and, in some cases, marked oxide debris has been observed between two specimens of this material. When the applied tangential force is below the value necessary to cause definite slip, no perceptible corrosion takes place. The presence or absence of slip appears to be a definite criterion as to whether contact-corrosion will occur.

Welded Joints

There exists a great need for a reliable non-destructive method of testing a welded joint. Many forms have been tried, involving X-ray, magnetic, electrical, and acoustical methods. That the X-ray method is undoubtedly the best represents an agreed opinion, and it is clear that this method is being adopted in service to an increasing extent. Regarding the reliability of the X-ray method of testing, many are enthusiastic, but others are more cautious. If defects in a weld are so minute that they cannot be detected by X-rays, they certainly cannot be detected by any other method; this is a fair summary of the present position. But great difficulties arise when complicated shapes are involved; also, in large structures or fabrications, the cost of X-ray examination brings in an economic aspect of the greatest importance.

When repairs to existing engineering works are effected by welding, the thermal stresses induced may be very serious. Valuable mechanical tests are reported on the amount of these stresses and their influence on the strength of repaired structures. In general, tensile stresses are called into play; the effect of repairing, by welding, a member in a state of compression may thus throw that member entirely out of active commission, imposing additional stresses on its neighbours. Considerable experimental evidence is advanced showing that, in the case of tension members, girders, repaired and strengthened by welding, little influence is exerted, in general, on the *stress* induced at failure, while the total *resistances* of the constructions has been considerably increased; it may not, however, follow that the fatigue resistance of these repaired structures is also unaffected by the presence of severe thermal stresses, and some experiments to investigate this aspect would be very valuable.

Cracking of Boiler Plates

One type of boiler failure, commonly called "Caustic embrittlement," is definitely associated with inter-crystalline cracking, *i.e.*, the cracks in their general path follow the grain boundaries and do not run through the crystals—which is the usual course of fracture in ductile metals.

(*Continued on page* 185.)

Evolution and Development of Steel-making Processes

In his Presidential address to the Staffordshire Iron and Steel Institute at Birmingham recently, Mr. J. T. Wright *outlined the evolution and development of steel-making processes and referred to some of the great men who invented and partially perfected the various processes. Some extracts from his address are given in this article.*

PRIOR to 1856 only two methods of making steel had been employed—the cementation and crucible processes. The Wootz steel of India, the famous blades of Damascus, and the equally famous steels of Toledo, were all made by the crucible process, or a combination of the cementation and crucible processes. A brief reference to the manufacturing of these steels is noteworthy.

Wootz Steel.

The iron ore is generally picked up along the river beds in the form of small lodestones. These are thoroughly washed until separated from all clay and foreign matter, and subsequently pounded by large wooden mallets into powder. The iron dust is put on a bed of charcoal, and covered again with charcoal. The air blast (supplied by skin bellows worked by hand or foot) is introduced by bamboo tuyeres, covered with mud to the bottom of the hole. The product is a spongy mass which is beaten with wooden mallets, re-heated to a white heat and re-beaten into square bars. During the process of manufacture it is never allowed to become cold. The iron produced is converted in a crucible furnace.

Damascus Steel.

In Snya, the fame of the swords sold in the market of Damascus dates back to the time of Abraham, and the Emperor Diocletian had a sword factory for his army at this important commercial centre. For this purpose the highly carburised metal was afterwards partially decarburised by repeated heatings in an open charcoal fire. The forging was done with great care, using light blows and never heating the metal above a red heat even though it was necessary to re-heat frequently. After polishing the cold blade it was ready for "damascening" the surface—by immersing the blade in a solution containing some secret etching solution. The beautiful patterns of light and dark bands were taken as an index of the value of the weapon.

Great Men in the Development of Steel Making.

The gradual development of various processes was briefly discussed in which Mr. Wright dealt with the invention of the modern crucible process in 1704 by Huntsman, a clockmaker, and the Bessemer process (1856) by Henry Bessemer, an engineer who was looking for better material than cast iron for cannon. Robert Mushet's invention of the use of manganese in the Bessemer process played an important part in the development, and Sydney Gilchrist Thomas, a clerk in the Thames Police Court, perfected the modification of the process which enabled phosphoric pig iron to be converted into good steel.

Early Steel Works in Staffordshire.

It is very interesting to note that South Staffordshire has played an important part in the early development of the basic Bessemer process, and one of the very earliest Bessemer plants ever operated was established at the works of Messrs. Lloyds Foster and Co., Wednesbury, now the Patent Shaft and Axletree Co., Ltd. This firm can also claim to be one of the first to establish a basic open-hearth plant, and has continued to develop the open-hearth process since its inception.

In the early eighties, the late Sir Alfred Hickman, who up to that time was a producer of pig iron only, formed an auxiliary Company called the South Staffs Steel and Ingot Company, erected a steelworks and commenced the manufacture of basic Bessemer steel, and this Company has since erected a modern open-hearth plant. About 1870, the average capacity of the Bessemer converters was about 5 tons, but later was increased considerably, and to-day converters are operating on the Continent at capacities of 25 to 40 tons.

No mention has been made of the suitability of the steel made by the basic Bessemer process for all types of special work, but as basic Bessemer steel is ideally suited for tube strip, sheet bar and semi-finished products for re-rolling trades, there can be no shadow of doubt that the basic Bessemer process at Corby should produce a suitable steel which will enable them to successfully compete with imported steel.

Open-Hearth Process.

In 1867, Siemens took out a patent in which he claimed that "Steel could be directly manufactured from the ore—by melting together pig iron (containing manganese) and scrap iron or steel, or puddled iron—or by the simultaneous employment of both processes." Pierre Martin had developed a process simultaneously in France by using scrap in a bath of molten metal, and after considerable litigation, in which Martin became impoverished, the combination of the method became known as the Siemens-Martin process.

It was about this period that South Staffs began to take its rightful place as a steel-producing centre. Hithertofore, owing to its geographical position, the distance from the supply of hæmatite pig (an essential for steelmaking prior to the discovery of the basic process by Gilchrist Thomas), South Staffs could not compete economically with the more favourably situated steel-producing centres. Mr. Wright considered some of the modifications of the open-hearth process and the design of the furnaces and briefly outlined the types of electric furnace.

In conclusion reference was made to the aims and objects of technical institutions, like the Staffordshire Iron and Steel Institute, which encourage, support and further metallurgical research and enterprise, and Mr. Wright emphasised the debt of gratitude we owe to the great men who, by their patient research and perseverance, invented and partially perfected the various steel-making processes. There are hosts of scientists, engineers, and others, who have nobly played their part in the successful development of the various processes. Although their contributions may be undeservedly forgotten, it should prove a source of encouragement to the younger generation of scientists and engineers to remember, that no great achievements or inventions could possibly have been developed had it not been for their important work which laid the foundation stones of this tremendous industry, and thereby enabled the world to produce the enormous quantity of steel now employed.

The Company known as The Patent Gear and Metal Hardening Co., Ltd., which has for a number of years carried on business in the hardening of gears and other metal parts, under the "Shorter" patents, has changed its name to Shorter Process Co., Ltd., and its head office and main works are in Sheffield; the address being Celtic Works, Saville Street East, Sheffield, 4, to which all future correspondence should be addressed.

Bronze and Brasses Containing Lead

Improved Machinability

IN cast alloys comprising gunmetals, phosphor bronzes, manganese bronzes, and yellow brasses, the presence of at least a trace of lead is almost universal. It is present in high-grade engineering brasses and bronzes to the extent of from 0·1 to 1%, and general castings ordinarily used for low-stressed parts frequently contain up to 5% lead. There is also a distinct though smaller class of copper alloys which contain large amounts of lead as an essential constituent. This comprises statuary bronze, leaded bearing bronze, and so on. Apart from these alloys, however, lead is a constituent not essential to the ordinary usage of brass and bronze, and the majority would function as well in service without any lead content. Its presence can only be explained, therefore, by reference to secondary considerations.

The suggestion that most cast brass and bronze might work, in service, quite as well without as with a small lead content, is not sufficient reason to regard lead uncompromisingly as an impurity to be eliminated, and to infer that its presence is harmful. This attitude is somewhat prevalent among engineers, and is due mainly to the lack of a full understanding of the function and behaviour of lead. There are also to be noticed in technical literature occasional claims made, with rather more enthusiasm than justification, for one or another outstanding improvement which lead is supposed to confer upon brass and bronze, and such over-statements, in time, naturally rebound to the discredit of lead.

From the commercial point of view, lead is often under suspicion simply because it is much cheaper than the other constituents of brass and bronze, and nefarious attempts at adulteration are thus often ascribed to manufacturers who desire to include a little lead in their alloys. Such a point of view is particularly unfortunate, because the inclusion of lead can often only be justified on account of its conferring manufacturing advantages, and these advantages are quite unconnected with the price of lead itself. Thus, in many cases a hasty elimination of lead may react to the buyer's disadvantage by greatly increasing the price at which his orders can be economically manufactured.

The suspicion with which lead is commonly regarded is reflected in many of the well-known specifications issued by official and public bodies. Before one can judge the value or necessity of restrictions on the lead content of cast brasses and bronzes, it is necessary properly to assess its effect from several points of view. The effect of lead must be studied in relation to the constitution, properties, and manufacture of these alloys.

The constitution of brass or bronze is entirely unaffected by lead, since it is practically insoluble both in the liquid and solid alloys. In the cast material, therefore, lead is present as more or less globular inclusions of structurally-free pure metal, and the alloy itself crystallises in its normal fashion just as if no lead were present. When a piece of brass or bronze is polished during the preparation of a micro-section, the free lead, which is very soft, is rubbed out of the surface, and tiny holes are left in its place.

It has to be remembered that during the cooling of a brass or bronze casting, the lead, on account of its insolubility, is liquid down to 327° C.—long after the rest of the alloy has frozen. It takes up its position in the interstices of the brass or bronze crystallites the location of which depends upon the manner of the freezing of the alloy. In brass, for example, the rate of freezing, due essentially to the long freezing range of these alloys, has a particularly important effect on the crystal structure and, in consequence, on the distribution of the lead. If the cooling rate is slow, there is a tendency towards the formation of large coarse crystals, during the growth of which the lead is pushed to the crystal boundaries, where it can agglomerate into massive pools. On the other hand, with very rapid cooling a finer crystallisation is induced, and the lead is trapped in fine particles throughout the dendritic structure.

The main reason for allowing the addition of any lead to brass and bronze is that an improvement in the machinability of the alloys is gained thereby. Lead-free alloys machine with surprising difficulty, considering their relative softness. A slight improvement in the machinability of pure bronze is gained by additions of phosphorus, but it is not possible to add phosphorus to zinc bronzes. The pure brasses also are more difficult to machine than the complex alloys, and some improvement may be gained by additions of tin and iron. There are, however, disadvantages to both these impurities. For example, the addition of tin increases the price of brass, and the addition of iron introduces a liability to rusting. The addition of a small amount of lead to any of these alloys brings about a surprising transformation far beyond that obtained by any other addition.

When machining lead-free alloys, the turnings come away in long awkward spirals, and if the cutting speed is higher than a very slow rate the metal quickly overheats. After the addition of a small amount of lead it is difficult to believe that it is the same basis alloy which is being machined. The turnings now clip off in small, heavy curly pieces, and cutting speeds can be put up to the full capacity of the machine tool. The amount of lead necessary to bring about this change varies somewhat with the different alloys, but in all cases is quite small. Gunmetal requires only 0·5% lead to make it free cutting, and additions beyond 0·5% effect very little further improvement in the cutting with as little as 0·5% lead, but further improvement is gained by increasing the lead up to 2%. Above 2% lead in brass improves the machinability scarcely at all.

Production of Vanadium and Titanium in U.S.S.R.

As a result of years of experimenting, Soviet scientists have succeeded in producing vanadium and titanium of such quality and in such quantities as to make the Soviet Union independent of foreign imports of these metals.

Ferro-vanadium, in addition to being an alloy that imparts elasticity to steel, increasing its tensile strength, is used in the manufacture of aniline black, vanadium inks, mordants for dyeing and photographic developers. Titanium, as an alloy with steel, gives hardness and toughness to that metal. It gives a fine, brilliant lustre to silver. Titanium in various forms is employed in dyeing and in making paints for the protection of iron from the air. Electrodes for arc lights, composed of titanium carbide, give twice as much light as those made of carbon.

Solution of the problem was found in the discovery that titanium ore, which contains ferro-vanadium and titanium, could be melted in blast-furnaces. For a number of years Soviet scientists have been experimenting with various methods of melting the ore. Academician Pavlov, in 1929, tried the blast-furnace method, but without satisfactory results. Then Professor Shadlun found a way to separate the titanium from the ferrous component of the ore before melting. The Ural Institute of Rare Metals pursued Professor Shadlun's experiments further, and improved upon them.

At the recent annual meeting of the Staveley Coal and Iron Company the chairman, Sir William Bird, stated that in the near future plant was to be installed for the manufacture of sodium chlorate. At the present time, he said, there was no plant in the British Isles for the manufacture of sodium chlorate and the company felt confident that they could compete successfully with colonial and continental makers.

Inspection of Materials in Automobile Engineering

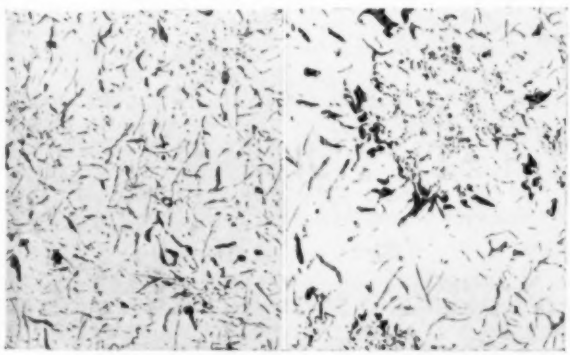
In this article routine tests are discussed with particular reference to the methods employed by a well-known firm of British car manufacturers; some metallurgical features and developments are also described.

THE choice of the material for a particular component in motor-car construction is determined largely by such factors as strength for weight, reliability, and suitability for forming, by the method to be employed, into the desired shape. Reliability, involving, as it does, freedom from defects, relies to a considerable extent upon ductility and freedom from brittleness. In order to satisfy requirements, specifications have been developed embracing a wide range of ferrous and non-ferrous metals and alloys. But while specifications may be to a large extent protective, they do not always ensure that the material supplied is consistent with requirement. Despite the fact that responsible manufacturers of metals and alloys in the finished and semi-finished condition have made remarkable progress in recent years in maintaining regularity of composition, eliminating harmful impurities, and in obtaining definite physical properties and structures, especially suitable for particular service conditions, there is a considerable amount of inferior material manufactured and this must be guarded against in motor-car manufacture.

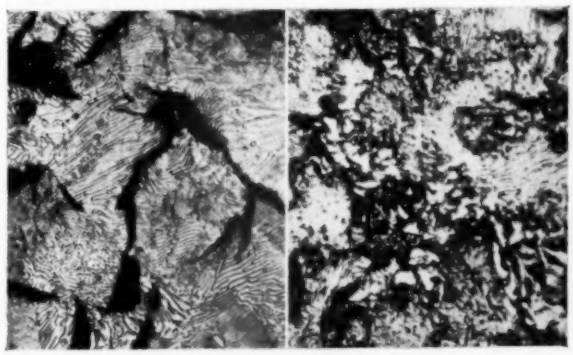
Inspection and Testing at Morris Works.

The first essential in the manufacture of Morris cars is the strict examination of all incoming material for any deviation from the correct chemical analysis, mechanical properties or micro-structure. The latter form of testing is probably more thoroughly carried out than is usual in engineering works, a typical example being crankshafts, which are made in a high manganese-nickel steel, heat-treated to give an Izod impact figure in the region of 80-ft. lbs. These are bought in the forged and heat-treated condition, and a number are examined from each consignment for micro-structure, and tested for the presence of nickel, in addition to frequent tests for chemical analysis and mechanical properties; the hardness of every crankshaft is determined by means of the Brinell test. A similar procedure is carried out in the case of connecting-rods, except that all consignments are analysed on delivery as well as being submitted to Brinell test after heat-treatment. These two examples are typical of the testing carried out on materials received at these works, and any deviation from the specified figures being sufficient to causerejection of the whole consignment.

The all-core method in cylinder production enables the use of a harder iron.



No. 1. All core. × 50 *No. 2. Green sand.* × 50



No. 3. All core. × 500 *No. 4. Green sand.* × 500

Unfortunately for the engineer there is frequently no difference in appearance, either in the rough or machined condition, between suitable and unsuitable materials for a given component; even a simple test such as analysis or tensile strength is not capable of revealing fundamental differences. To maintain high quality in motor-car manufacture it is therefore essential to be as sure as is reasonably possible that the materials passed into service satisfy the specifications laid down for them.

Reliable manufactures have long recognised the need for metallurgical inspection and testing of metals and alloys used; in many cases the technique developed is of a comprehensive character. The main object is to ensure that all material is good from the point of view of analysis and physical condition, not only in bars, billets, sheets, etc., but in forgings, stampings and castings, and to this end all material is tested both before and after heat treatment, if heat-treatment is required. Micro-examination is also frequently made, and photographs taken showing condition, grain-size, inclusions, or any other interesting or important feature. It is this constant metallurgical and physical control of material which ensures quality of production and reliability in service. Some indication of the thoroughness of this work is given in the following typical example, which by the courtesy of Morris Motors Ltd., we are permitted to publish.

Metallurgical Features in Morris Cars.

Actual steels employed follow normal practice. A high quality nickel-chrome case-hardened steel is used for the gearbox gears, 5% nickel case-hardened steel being used for other parts of the gearbox. High manganese nickel steel is employed for the front axle beam, nickel-chrome-molybdenum steel, heat-treated to give upwards of 70 tons per square inch, for drive shafts, 3% nickel steel for steering parts, heat-treated to give upwards of 50 ft. lbs. Izod impact figure, while important studs such as cylinder-head studs and bearing studs, are made of heat-treated manganese-molybdenum steel having a tensile of 50 to 60 tons per square inch, and an Izod of well over 50 ft. lbs.

In connection with this latter steel, it is noteworthy that a recently introduced method of estimating the

molybdenum is employed in the laboratory, the element being precipitated by the use of a solution of A-Benzoin Monoxime.

The valve steel used possesses excellent resistance to oxidation, tests showing a much slower rate of oxidation under similar conditions over that of the older type of steel. Among other steels employed are 55-ton nickel-chrome steel and stainless steel.

One of the most interesting alloys at present employed is that used for pistons, this being an aluminium alloy having a much lower coefficient of expansion than the older type of aluminium piston alloys, in addition to increased hardness. This has the effect of giving all the benefits of cast-iron pistons without the disadvantages usually associated with aluminium pistons.

Foundry Development.

Probably the most outstanding metallurgical feature of Morris car production is to be found in the foundry, in the method of moulding, the cylinder moulds being built up entirely of oil sand cores, the process being known as the "all-core method." In this way all green sand is obviated, a harder iron being permissible owing to the absence of the danger of chilling in thin sections. The quality of the metal in the bores themselves is much higher by this method than when produced by the conventional method, the latter method producing castings which are harder on the outer surfaces than in the centre, so that to ensure reasonable machineability a cylinder block cast by the latter method has, of necessity, a comparatively soft cylinder bore. Uniformity of cooling in the oil sand mould ensures the hardness of the bores being similar to that of other sections of the block, enabling the general hardness of the casting to be increased without fear of hard spots.

The photo-micrographs show the difference between the cylinder bores. No. 1 shows the bore in the unetched condition, cast by the "all-core" method; No. 2 showing the structure of the bore cast by the more conventional green sand method. The former shows the graphite to be uniform in size and in the flaky condition, this being the best condition for resistance to wear, while the latter shows a large amount of the eutectic graphite, this being associated with a lower hardness, and therefore, increased wear. Nos. 3 and 4 show the structures of the matrix, No. 3 referring to the bore of a block cast by the "all-core" method, and No. 4 the structure of a bore cast in the usual way. No. 3 has a higher combined carbon content than No. 4, owing to the use of a harder iron.

The Testing of Engineering Materials.

(*Continued from page* 184.)

That many failures of boilers in service occur by inter-crystalline cracking there is no doubt, but in spite of many attempts that have been made, it is extremely doubtful whether laboratory conditions have reproduced exactly the characteristics of these failures.

In general, it may be said that failures of this type occur in boilers at positions where regions of localised stress exist, as in the riveted seam, usually under the rivet heads, or through the rivets at the junction of the plates, or in the plates between the rivets; they have been observed in plate material of excellent quality as well as in material of inferior grade. In such enclosed regions, the proportion of caustic present may, owing to evaporation, considerably exceed the average concentration of the feed-water supply. It is now commonly agreed that this type of failure is a combined effect of high local stress and chemical attack; also, it is extremely likely that the required conditions are critically balanced. Some lines of attack on this problem, now being pursued at the N.P.L., are described, but at the present time the experiments have failed to reproduce typical caustic embrittlement.

Fatigue of Metals.

In practically every branch of engineering, design against failure under service conditions is, or should be, much more related to the resistance of materials to fatigue stresses than to mere static or dynamic stresses. The truth of this statement is evinced sufficiently both by the estimate that 90% of service failures have been ascribed to fatigue, and by the vast amount of experimental attention that has been devoted to the study of fatigue phenomena; to this study the N.P.L. can claim to have contributed many valuable researches. In this paper the authors made brief reference to some aspects of major importance to engineers at the present time. To begin with, we require to know the fundamental aspects of fatigue failure: the acquisition of this knowledge necessarily implies the employment of methods of investigation which are scientific rather than technical, but, as past experience has shown, undreamed-of fields of technical and industrial development usually result from the firm establishment of basic scientific principles. Many data exist regarding the fatigue limits of metals; the data are, however, usually acquired from tests made on small specimens of carefully prepared form and surface finish. But the finished practical component often does not correspond to the condition and shape of these test-pieces. In the first place, owing to the method of manufacture, *e.g.*, in casting, forging, or heat-treatment, the surface often differs considerably from the interior material, and it must be remembered that, in general, the most severe service stresses are set up at a free surface. Then again, for technical reasons, the *form* of the component suffers sudden changes in shape, due to transition fillets, imperfect machining, oil holes, screw-threads, etc., and the presence of these causes local concentrations of stress which may seriously and adversely affect the fatigue strength. Thus, two fatigue aspects of current major importance may be described as "surface effects" and "stress concentration effects."

An extremely valuable discussion of the present state of knowledge of stress concentration effects, principally in relation to marine-engine design, has quite recently been published in a paper,* in which the importance of the problem is so clearly brought out that little more remains to be said until further experimental evidence and data become available; research in this field is urgently required.

Failures in Service.

The investigation of service failures offers a fascinating and instructive field of inquiry, often demanding the widest knowledge of the properties of materials and a balanced appreciation of the possibilities and limitations of testing methods coupled with keen observation and attention to detail. A great variety of failures, drawn from all branches of engineering, are received at the N.P.L. for investigation, and in this paper the authors indicate the general methods adopted, which are illustrated by a few examples. They state, the most common cause of service failure is that of fatigue; many failures are due to stress concentration effects, such as sudden changes of section, deep machining marks, transition fillets of insufficient radius, the placing of oil holes, or location holes, at high-stressed regions, etc. Unfortunately, it is clear that the marked effect of stress concentrations on fatigue resistance is not yet sufficiently realised either in the drawing office or the workshop.

Personal.

Mr. Henry Butler Allen, metallurgist of the Henry Disston Company, Philadelphia, and member of the Board of Managers of The Franklin Institute for several years, has been elected director of the Museum of The Franklin Institute. He started on his new duties the beginning of this month.

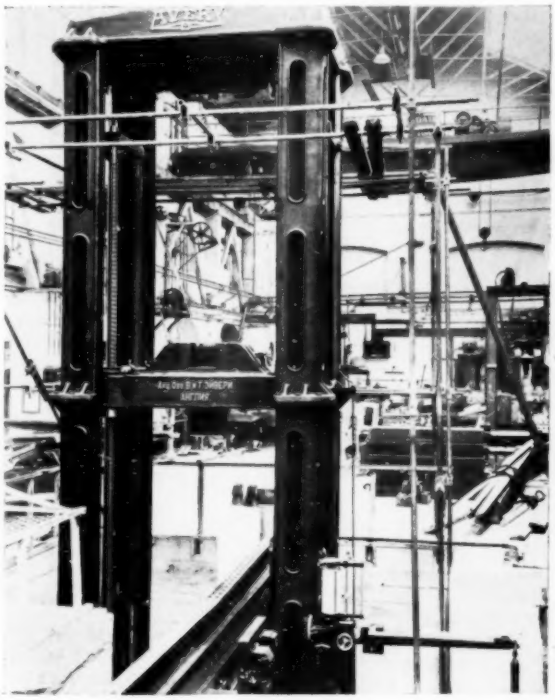
Mr. Herbert Clark has been appointed Managing Director of Messrs. Tangyes, Ltd. This marks another interesting step in the career of Mr. Clark, who was for many years associated with automobile and allied engineering.

* "The Relation of Fatigue to Modern Engine Design," MacGregor, Burn and Bacon. Trans. N.E. Coast Institution of Engrs. and Shipbdrs., Vol. 6, January, 1935.

Recent Developments in Materials, Tools and Equipment

Compound Lever Testing Machine with a Capacity of 180,000 kg.

A TESTING machine of unusual size has recently been designed and constructed by Messrs. W. and T. Avery, Ltd., for export to Russia. It is a compound lever testing machine, and has been designed to accommodate large specimens for carrying out tests in tension, compression and transverse bending. In tension specimens can be tested from 75mm. to 5,000mm. stretched length ; compression up to 6,000 mm. ; while the maximum effective span for the bending tests is 7,000 mm., with a maximum capacity of 100,000 kg. The machine is arranged with four straining rods, giving ample space between the rods for inserting the transverse specimens, and a hydraulic cylinder for imposing the testload, together with extremely sensitive and accurate weighing levers for indicating the load applied.



The machine erected for testing and calibration preparatory to being exported.

The weighing system incorporated with the machine is of Avery's special design consisting of a main lever system, totally enclosed. Every precaution has been taken in the design and construction of the levers to ensure accuracy of movement, and the levers are connected to the steelyard by a connecting-rod and shackle. The steelyard scale is machine engraved from zero to the full capacity of the machine by divisions of 1,000 kgs. A micrometer screw dial sub-divides these readings into 10-kg. divisions. The poise is machined to suit the steelyard, and is traversed by a machine-cut screw which simultaneously rotates the micrometer screw dial.

For the tension test three sets of wedges are provided to take round bars as follows :—

1 Set 15-mm. dia. to 20-mm. dia.
1 Set 20-mm. dia. to 30-mm. dia.
1 Set 30-mm. dia. to 40-mm. dia.

The wedges are fitted in the straining crosshead and the weighing crosshead, and each set is directly controlled by a handwheel. The two wedges in each holder are also interlocked, so that they move together. The straining crosshead can be adjusted on four screws to within 75 mm. of the weighing crosshead, thus enabling very short tensile specimens (say, down to 50 mm. gauge points) to be tested. Limit switches are provided to prevent the crosshead overrunning in either direction.

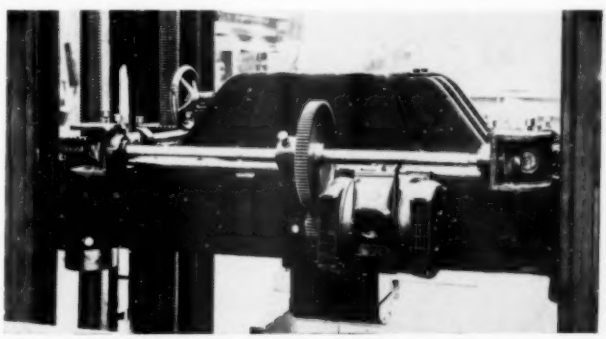
Compression Testing

The compression test is carried out by placing the specimen between the straining crosshead and the compression platen on the surface of the weighing platform. A maximum length of six metres can be accommodated. A compression platen suitable for 380-mm. square maximum specimen is provided for the compression test, and this rests upon the surface of the weighing platform : it consists of a bearing block with a spherical seat to carry the platen block with a spherical under-surface. The sphere is generated from the centre point of the compression face of the platen block. The block is square and is provided with set-screws on the corners to hold the block in position while the specimen is being set up.

For transverse tests bending-dogs 380 mm. wide and 610 mm. high are provided, and the span is adjustable from 1,200 mm. to 7,000 mm.

Mechanical Features

The strain is applied to the specimen through the medium of a hydraulic cylinder and ram operated with mineral oil. The ram is a close-grained iron casting with a ground surface, and is connected to a crosshead which



A view of the straining crosshead showing the adjustment gearing and motor.

receives the four straining rods of the machine. The hydraulic pressure is retained between the gland and the ram by "U" leathers and by cup leathers in the ram itself. The cylinder and ram are designed to give a quick return after the test with a minimum expenditure of oil.

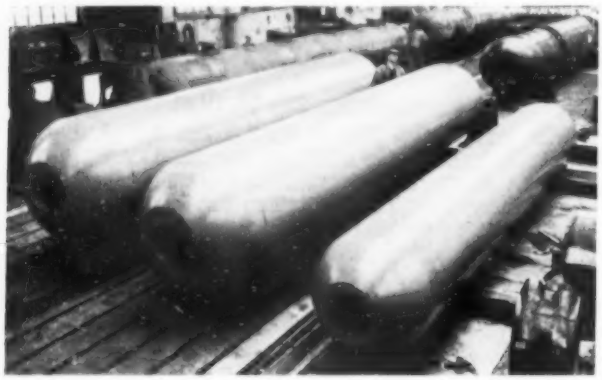
The hydraulic supply to the cylinder for straining and returning is controlled by a handwheel incorporated in the pumping unit. A feature of this handwheel control is fine speed regulation in either direction. The pumping set is placed in a suitable position so that the operator has control of both the pump handwheel and the handwheel for propelling the poise along the steelyard.

The maximum straining speed obtainable with the pump motor running at approximately 710 r.p.m. is 50 mm. per min., and the maximum return speed in the upward direction is 450 mm. per min.

Business Notes and News

Solid Forged Boiler Drums

In face of keen competition and very urgent delivery requirements, the English Steel Corporation recently obtained an order for six solid forged boiler drums from the Combustion Engineering Corporation Limited, of Montreal, for two boilers being installed at the Ford Plant at Walkerville, Ontario, which boilers we understand are the first of their type to be erected in Canada. The English Steel Corporation have vast experience as makers of forgings, and have supplied large numbers of similar drums for many of the super power stations in this country.



One set of three boiler drums in the machine shop of the English Steel Corporation just before dispatch to Canada. The steel ingots required per set weighed approximately 68, 48, and 39 tons, respectively.

To take an order such as the one referred to in face of keen competition is an achievement, but more important is the fact that the remarkably quick delivery promised was beaten handsomely. This could not have been accomplished had it not been for the recent complete modernisation of the steel melting, forging, heat-treatment and machining plant at these works.

Dudley Works to be Reopened

Messrs. Barton and Sons (1935), Ltd., of Walsall, have purchased a three-acre works at Dudley which has been vacant for five years, and are to reopen it in a month. Their object is to increase their output of drop stampings for the motor and cycle trades, the manufacture of which is carried on by their subsidiary concern, Clydesdale Stampings, Ltd., at Old Hill, Staffs., and Birmingham.

Steel Producer's Staff Pensions Scheme

That the future of staff employees in the heavy engineering industry should be made secure is a problem exercising the minds of many large-scale producers in British industry. In his speech, made at the annual meeting on October 2, Mr. W. Benton Jones, chairman of the United Steel Companies, Ltd., who produce one-sixth of the steel made in this country, and who have works as far apart as Yorkshire and Northamptonshire, Cumberland and Lincolnshire, showed how this important Company is taking care of the future of its employees.

A contributory life assurance and pensions scheme, for voluntary acceptance, has been inaugurated. The scheme is particularly interesting, as it provides for not only the staff, from the junior typist to the highest paid official, but foremen and establishment men. It provides both annual retiring pensions for men at sixty-five years of age and for women at sixty, and life assurance of a substantial amount at any time up to pensionable age.

The scheme is important from the social aspect, as it is one more attempt to improve the stability of employment in the heavy industries, and to show that the personal welfare of the employee has not been forgotten with the increase of size in producing units. A point of some importance, which has called for a substantial contribution from the Company, is that long service, prior to the date of establishment of the scheme, has not been overlooked. For each year of service, from the age of twenty-one to the date of the commencement of the scheme, pensions are reckoned at half rates. The eligible members of the staff of the United Steel Companies, Ltd., have quickly grasped the opportunity afforded, and already 99·5% have enrolled.

Progress of British Steel Industry

Dealing with the expansion in British iron and steel production at the recent general meeting of United Steel Companies Ltd., Mr. Walter Benton Jones (chairman) showed that this had been effected by the displacement of foreign steel. Figures showed that in 1935, judged by the first half of the year, the country would have produced as much as in 1929, and 1,412,000 tons more than it would have produced if imports had not been checked. Home consumption in the present year had surpassed 1929, and exports had risen appreciably above the level of 1932. The true significance of the figures given might well be an indication that the demand for British steel in the future would be at a higher level than it had been in the past.

The United Steel Companies Ltd. have contributed to this expansion, and during the past twelve months has produced more steel than in any previous year of its existence, namely, 1,351,600 tons, and during the present twelve months has maintained this high level of steel production with a comfortable margin to spare. Production of pig-iron and coke has been substantially greater, and the output of coal also shows an increase. Sales reached a higher level in home markets and there was a substantial advance in export sales.

The operating profits of the company have increased by £150,000. Selling prices have not advanced, and our larger profits are the result of a higher rate of production and economies in the cost of operation. In the coming year, Mr. Jones stated, the new coke-oven batteries at the Rother Vale Collieries Branch and at the Workington Branch would be put into operation. At Rother Vale also a large new coal-washing plant was being installed, and at Frodingham new finishing equipment was being added to the rolling mills.

Uruguayan Copper and Lead Ores For British Coal

It is announced that a contract has been signed between the Uruguayan Administration of Electric Power Houses and Government Telephones and the local representatives of a British firm, Messrs. Evan Reid Coal Co., Ltd., under which that Company, in combination with the British Metal Corporation, undertakes to furnish 100,000 tons of steam coal in exchange for copper and lead ore taken from the mines worked by the Uruguayan Government enterprise in question. It is estimated that the entire fuel consumption of the Uruguayan Government enterprise for 1935 will be paid for in this manner, and that the value of the coal purchased is about £120,000. The British firms in question are stated to have previously sent experts to Uruguay to investigate this scheme. Further sales of other ores to various countries are contemplated.

Catalogues and Other Publications.

An interesting and informative brochure has been issued by Messrs. Head, Wrightson and Co., Ltd., Teesdale Iron Works, Thornaby-on-Tees, dealing with heat-resisting steels. For some years this firm has manufactured heat-resisting steels for a variety of uses, and, as a result of the success achieved with these steels, they are now divided into three groups, which are named "Shadrach," "Meshach," and "Abednego." This brochure describes the properties of these steels, and gives useful information on their uses.

A useful booklet has been published by Firth-Vickers Stainless Steels, Ltd., which gives concise information on the manipulations of three categories of corrosion-resisting steels. It deals with Firth-Vickers stainless steel, S 80 stainless steel, and "Staybrite" steel, and the information given will be particularly valuable to foremen, charge-men, and all who are actually engaged in the fabrication of these materials. Copies are available on application to Firth-Vickers Stainless Steels, Ltd., Staybrite Works, Sheffield.

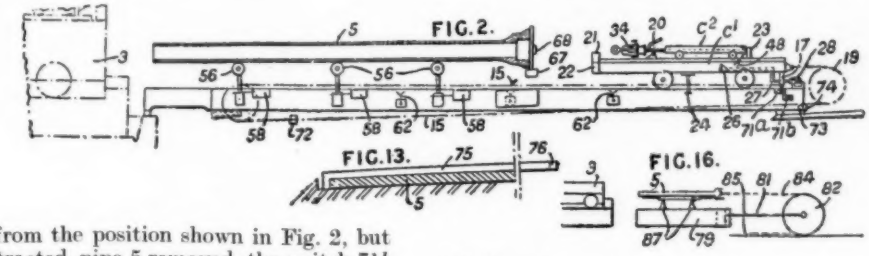
A temperature chart has been prepared by the Research Department of Hadfields, Ltd., which shows the wide range of industrial temperatures for which the various special steels supplied by this firm are suitable. The characteristics of the alloy suited for use at various temperatures, ranging between almost absolute zero and 1,300° C., and their compositions are indicated. Engineers using alloy steels will find this chart very useful. Copies may be obtained from Hadfields, Ltd., East Hecla Works, Sheffield.

Some Recent Inventions

The date given at the end of an abridgement is the date of the acceptance of the complete Specification. Copies of Specifications may be obtained at the Patent Office, Sale Branch, 25, Southampton Buildings, London, W.C. 2, at 1/- each.

Casting Machines.

A RECENT development associated with centrifugal machines for pipe casting, relates particularly to a method of extracting the castings. After casting a pipe in a centrifugal inclined mould 3 during its downward movement, the cast pipe is extracted from the stationary mould. The mould is then cleaned and a socket core fitted so that when moved up it is ready for the next cast. The pipe may be extracted by a clamp 34 carried by a truck having a short free movement, limited by stops on a truck C^1, which is reciprocated by a rope and wheel driven by an electric motor controlled by switches.



Starting from the position shown in Fig. 2, but with the extracted pipe 5 removed, the switch 71*b* is closed by hand to move the truck C^1 upwardly to the left to introduce the clamp into the socket end of a pipe in the mould, a stop 22 on the truck C^1 acting on an arm 67 to withdraw a stop 68 and an arm 24 reversing a series of two-way valves 62 controlling fluid pressure supply to cylinders 58 which thus lower a series of roller supports 56. The truck C^1 is arrested by the stop 72 on the rope 15 opening the switch 71*b* and then engaging a positive stop 73. The clamp 34 is then expanded by moving a handle 41, Fig. 7, in the direction of the arrow this acting through rods 39, 37 to move a wedge 36 to the right. Switch 71*a* is then closed and the truck C^1 moves down to the right and, when stops 20, 20^1 engage, the truck C^2 is moved also to extract the pipe, the arm 24, Fig. 2, reversing the valve 62 and thus raising the rollers 56 to support the pipe. The truck C^1 is arrested by its arm 17 opening a switch 71*a* and a stop 74 on the rope engaging the stop 73. Before the truck C^1 actually ceases to move a stop 28 engages a spring-pressed arm 27 which has a projection 26 to engage a roller 48 on the lever system for operating the chuck and thus collapses the jaws 34 as shown in Fig. 7. At the same time projection 22 engages the arm 67 and thus moves the stop 68 into the path of the pipe 5. The truck C^2 is then free to run down to the right and is arrested by the stop 23.

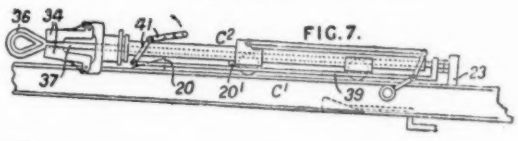
If the pipe 5 sticks or breaks in the mould it is extracted by a hook 75, Fig. 13, having a handle 76 which can be engaged by hooks 21 on the carriage C^1. In a modification, the clamp is attached to a chain 84, Fig. 16, which passes over a wheel 82, on a piston rod 81, and is fixed at 85 so that when fluid is admitted to a cylinder 79 the pipe 5 is pulled out of the mould on to supports 87.

426,172. SOC. ANON. DES HAUTS-FOURNEAUX and FONDERIES DE PONT-A-MOUSSON, Pont-a-Mousson, Meurthe and Moselle, France. [Class 83 (i)].

Iron-Chromium Alloys.

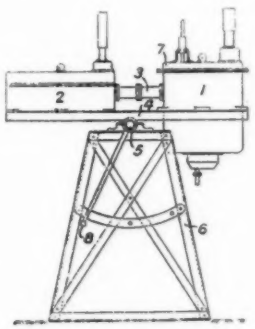
LOW-CARBON iron-chromium alloys of the rustless iron or steel type are made by melting down rustless iron or steel scrap with or without low-carbon steel scrap with slag-forming material to produce a bath of molten alloy with a strongly oxidising supernatant slag containing iron and chromium oxides, and thereafter adding a non-carbonaceous exothermic reducing agent—*e.g.*, a silicon-containing agent, preferably with lime to reduce the iron and chromium oxides, the chromium content of the melt being increased by the addition of chrome ore—*e.g.*, chromite,—all or the major portion of which is included in the original charge. The molten charge is initially superheated to a temperature of at least 3,050° F. before the addition of the reducing material. When the major portion of the chrome ore is added with the melt-down charge, part of the ore, up to 33% of the total, may be added during or subsequent to the melt down; the rest of the chrome ore up to 20% is then added with the reducing agents. The preparation of an alloy containing 0·08% of carbon, 17 of chromium, 0·35 of silicon, and 0·40 of manganese is referred to in the specification. The iron-chromium alloys may also contain 0·1—8·0% of copper, 0·1—35 of nickel, and 0·1—3·0 of tungsten, molybdenum, and vanadium.

428,950. Alloy Research Corporation, Edison Highway, Baltimore, U.S.A. [Class 82 (i).]



Refining and Casting Non-ferrous Metals and Alloys.

CERTAIN non-ferrous metals and alloys, for example, aluminium, zinc, copper, and their alloys such as aluminium-silicon alloys, aluminium-copper alloys, aluminium-zinc alloys, and copper-zinc alloys, are refined by blowing or bubbling through the molten metal a gaseous halogen, preferably chlorine, or a volatile halide or oxyhalide, or mixture of these gases or vapours. The metal is maintained in a non-oxidising atmosphere and is then cast in a mould in which a non-oxidising atmosphere is maintained, the treatment of the metal being effected under a pressure greater than atmospheric pressure.



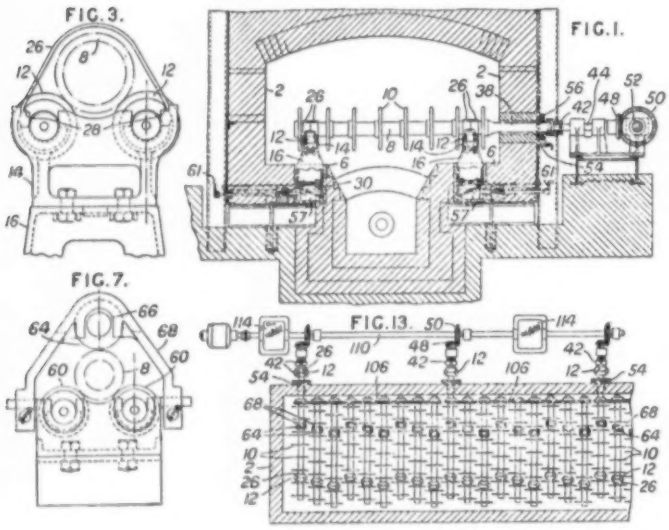
The volatile halide may be, for example, boron trichloride, vanadium tetrachloride, or vanadium oxytrichloride. The process is preferably carried out in a ladle 1 which is fitted with a gas-tight lid 7 and is connected to a mould 2 by a pipe 3, the ladle and the mould being mounted on opposite arms of a frame 4 pivoted at 5 on a supporting structure 6, a handle 8 being provided so that after the refining process the frame can be tilted to transfer the metal from the ladle to the mould. The ladle is provided with tuyeres for the introduction of the halogen or halide under pressure. The air is driven out by the halogen, etc., through a weighted non-return valve of through a restricted opening in the ladle or mould, and the halogen and the reaction products of the halogen and the metal constitute a non-oxidising

atmosphere at a pressure above atmospheric in the ladle and mould.

420,694. D. R. TULLIS, Somerfield, Manor Drive, Sutton Coldfield, and P. OAKLEY, The Tower, Rainhill, Liverpool, [Class 82 (i)].

Conveying-furnace Charges.

IN a furnace having a conveyer consisting of driven rollers carrying charge-supporting discs, the rollers, which rest on one or more bearings within the furnace chamber, terminate, at one end, short of the side wall and, at the other end, have extensions which pass through apertures in the opposite wall and are connected by flexible couplings to driving shafts. The latter are driven through bevel gearing, and the apertures through which the roller extensions pass are sealed by heat-insulating material enclosed in sheet metal containers.



Each bearing comprises a pair of rollers supported in bearers secured to the upper end of a pedestal, which is adjustably mounted in the furnace floor. As shown in Fig. 1, the pedestal has secured to its lower end a wedge-shaped part resting on a similarly shaped member, which is moved horizontally, to raise or lower the pedestal, by a shaft having a crank handle at its outer end. The roller is retained in position on the bearing rollers, and access of dirt and scale to the latter is prevented by a two-part hood, which is welded at 28, Fig. 3, to supports.

Fig. 7 shows a modified form of bearing in which, in addition to the rollers, 60, there is provided an additional "floating" roller 64, which rests on top of the roller 8, and is mounted for free vertical movement in recesses in a yoke. The arrangement of bearings shown in Fig. 1 is modified for exceptionally narrow or wide furnaces; in the former case one bearing is disposed within and another outside the furnace, while for wide furnaces each roller 8, which is formed in two sections connected by a flexible coupling, is supported by three bearings within and one outside the furnace chamber. Fig. 13 shows in plan view a further construction in which the rollers 8 are arranged in groups, the rollers of each group being connected by driving chains, and the end roller only of each group extending through the furnace wall for connection through a flexible coupling to the driving gear. The main driving shaft is formed in sections between which are provided change-speed mechanisms to enable the speed of the several groups of rollers to be varied as desired. In this construction each roller 8 is supported within the furnace by two bearings, one being of the form shown in Fig. 3, and the other as shown in Fig. 7.

429,687. British Driver-Harris Co., Ltd., Gaythorn Mill, Albion Street, Manchester. [Class 51 (ii).]

The Zaporozhstal Metallurgical Plant.

ZAPOROZHSTAL, the iron and steel plant at Zaporozhe, in the Ukraine, turns out about 20% of the total quantity of high-quality rolled products produced in the Soviet Union. The plant, at present only one-third its projected size, will turn out, when completed, products nearly equal in value to those of the huge metallurgical combine of Magnitogorsk. It is practically a combine consisting of a number of big plants. The plant producing ferro-alloys turns out daily 200 tons of 45% ferro-silicon and 23 tons of refined and carbon ferro-chrome. The monthly output of the plant producing tool steel amounts to from 5,500 to 6,000 tons of high-quality rolled products. Its iron and steel works which, so far, has only two blast-furnaces of 950 cu.m. each, has a daily output of 1,500 to 1,600 tons of pig-iron.

A shop equipped with 30-ton electric furnaces will commence work this year and construction of a number of sheet rolling shops has also been commenced. The pig-iron products of Zaporozhstal form an item of Soviet exports. Although construction of the combine is still in full swing, the programme for this year's output amounts approximately to 130 million roubles' worth of products. The annual plan for pig-iron was fulfilled 71% during the last eight months, that for the production of ferro-silicon 68%, and for the smelting of ferro-chrome 68%, and for steel manufacture 69·1% During the last eight months the combine fulfilled its annual plan by 68·7%, and there is good reason to believe that the plan will be carried out entirely before the end of the year.

Zaporozhstal started as an independent enterprise a year ago, following reorganisation of the Dniepro Combine, out of which was formed a coal combine, an aluminium plant and Zaporozhstal During the period of its independent existence, Zaporozhstal has achieved a reduction of production costs. The plant was to have received a State subsidy of 35 million roubles. In the first quarter production costs were lowered by 3.96%, as compared with the previous year. Production costs in April were decreased by 14·4%; in May by 17·2%; in June by 6·2%; in June it was found possible to forgo one-half of the State subsidy. In July production costs were lowered by 22% as compared with last year, and in August by 21%.

The successful training of technical personnel enabled the plant completely to forgo the State subsidy in the last quarter of the year. This plant is practically the first of the newly-built iron and steel plants that has completely given up State subsidies.

The laboratory of the plant is one of the leading departments in the combine. Construction of a central laboratory, which will co-ordinate all the laboratory and research work within the plant, is nearing completion. The rule is not to send any product to the consumer without detailed analysis. It is planned to organise a scientific centre at the combine to investigate and study new steels and alloys. It is recognised that further progress of Zaporozhstal in its struggle for high-quality metal depends on this development. This plant is one of the most progressive in the Soviet Union, and there is every reason to believe that in 1936 the combine will be able to operate not only without a State subsidy, but on a profit basis.

A large order for steamers has just been placed in Moscow by the Machine Import Company, with Messrs. Furness Shipbuilding Company. This order is for seven timber carriers and involves a sum of more than £400,000. The order is to be completed within one year, and is one of the largest of its kind. The North Eastern Marine Engineering Company of Wallsend, will supply the engines.

Messrs. Fleming and Ferguson, Ltd., Paisley, have secured a contract to build a single-screw passenger and cargo vessel for the Newfoundland coasting trade. The vessel will be 250 ft. in length.

New Research Unit for the International Nickel Company

The International Nickel Company of Canada, Limited, is about to expand its research department in the direction of seeking further outlets for the utilisation of copper. A chemical and research laboratory is to be erected at Copper Cliff, Ontario, similar in many respects to the existing laboratory at Bayonne, New Jersey, and to the one now under construction at Birmingham, England. The laboratory will deal with projects leading to improvements in the process of refining nickel and copper, and, as stated, particular emphasis is to be directed towards the development of new uses for copper along the same lines successfully employed by the company in increasing the commercial uses of nickel.

The Soviet Aluminium Industry

During the first eight months of this year the aluminium plants of the Soviet Union produced 78% more metal than in the same period last year. The plan for 1936 is to produce approximately 50% more than in the present year.

Increased production in 1936 will be obtained mainly through more efficient utilisation of existing equipment, rather than by acquiring new equipment. For example, the Volkhov aluminium plant, the output of which is 6,000 tons, is to produce as much as 9,500 tons of aluminium next year without increasing its equipment. More powerful electrolytic baths will be introduced in the Dnieper aluminium combine.

To carry out the 1936 programme important changes are to be made in the organisation of labour. Though the output is to be increased, the same number of workers will be employed as during the last quarter of this year.

The technical processes of producing aluminium are to be greatly improved. In this respect, the Volkhov plant has set a striking example of efficiency.

Not only the aluminium plants, but also VAMI (Aluminium and Magnesium Scientific Research Institute) will radically reorganise its work. The Institute will cooperate more closely with the aluminium plants in developnew machinery and in improving existing equipment.

In 1936 the aluminium plants will not only supply aluminium wire bars and sheets as at present, but will also turn out large quantities of aluminium alloys to meet the needs of different Soviet industries.

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‡Manganese Metal 97–98% Mn.	lb.	0	1	2
‡Metallic Chromium	„	0	2	5
§ Ferro-Vanadium 25–50%	„	0	12	8
§ Spiegel, 18–20%	ton	7	10	0
Ferro Silicon—				
Basis 10%, scale 3/– per unit	ton	6	5	0
20/30% basis 25%, scale 3/6 per unit	„	8	17	6
45/50% basis 45%, scale 5/– per unit	„	12	5	0
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90/95% basis 90%, scale 10/– per unit	„	28	17	6
§ Silico Manganese 65/75% Mn., basis 65% Mn.	„	12	17	6
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